

**TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
PROJECT PLANNING BRANCH**

**DEVELOPMENT OF THE WATER RESOURCES
OF THE
FRENCH BROAD RIVER BASIN
IN
NORTH CAROLINA**

**CONDENSED
PLANNING REPORT NO. 60-100**

**KNOXVILLE, TENNESSEE
SEPTEMBER 1966**

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SUMMARY

SUMMARY

This report presents the results of a comprehensive study of development of the water resources of the French Broad River Basin in North Carolina as part of an overall program for economic advancement of the region. The plan for multiple-purpose development calls for a system of 14 dams, 74 miles of channel improvements, and 1.4 miles of levee at Asheville. The system would provide significant flood control benefits, as well as benefits from water supply, water quality control, recreation, shoreline development, fishing, and area redevelopment. The total estimated capitalized benefits for the project is \$143,000,000, and estimated cost of construction of the project is \$96,000,000.

The proposed system would reduce the depth and extent of inundation in all floods in the basin. Specifically, by reducing the flooding frequency on agricultural land downstream from one or two times per year during the crop season to not more than once in 5 years during a crop season, on the average, the proposed system would make it possible to farm these fertile lands more intensively with resulting higher crop yields. Immediately downstream from the dams, out-of-bank flooding would be reduced to not more often than once in 100 years. The capital value of the agricultural benefits would be \$34,200,000. The urban communities of Rosman, Brevard, Hendersonville, Fletcher, Enka, Asheville, Rollins, Biltmore, Marshall, and Hot Springs are subject to frequent and damaging floods. With the system of control planned a high percentage of such floods would be averted. It is estimated that the capitalized value of these benefits would be \$36,700,000. In addition to the agricultural and urban flood control benefits, it is estimated that benefits of \$1,300,000 would result from protecting U. S. and state roads, bridges, and railroads. Summarizing, the total flood control benefits to agricultural and urban areas, roads, and bridges would be \$72,200,000. To further limit potential flood damages and to avoid creating new flood hazards, the plan contemplates continued work with state and local organizations toward related land-use planning.

At the present time much of the French Broad River is highly polluted, a condition which is not conducive to expansion of existing industry or the attraction of new industry. After the pollution abatement facilities now under construction

by major industries and municipalities are completed, the harmful effects of the present pollution would be greatly reduced. However, streamflow regulation would be required to supplement secondary waste treatment of future waste discharges to prevent the recurrence of undesirable water quality in the streams. A related problem is the potential growth along the river of aquatic weeds and of obnoxious algae in the existing downstream Douglas Reservoir due to excessive concentrations of plant nutrients. The system would provide 76,200 acre-feet of storage capacity for streamflow regulation in the solution of these problems. The capital value of the water quality control benefits is estimated to be \$32,000,000.

Storage of 19,200 acre-feet of water for water supplies for industrial and municipal growth would be provided in five of the reservoirs. The capital value of the water supply benefits is estimated to be \$4,000,000.

The impoundments would replace 11 miles of trout streams within the basin, out of about 200 miles which were stocked in 1966. Four of the thirteen reservoirs, however, should be suitable for trout fishing. All in all, it is anticipated that the 6700 acres of lake area and 183 miles of shoreline, together with cooler water in streams downstream from the reservoirs, would enhance considerably the fishing potential of the area. The estimated capital value of these benefits is \$3,200,000.

Approximately 5300 acres of land adjacent to the reservoirs and above elevations reached by the maximum probable flood would be acquired in order to prevent unreasonable severance damage, avoid undue expense in providing access to isolated tracts, and ensure maximum development and use of the reservoirs for purposes of public benefit. The reservoirs would enhance the value of approximately 3600 acres of this land for such development and use. In addition, 4400 acres of adjoining land would be enhanced by the project and related development. These elements, taken together, produce shoreline development benefits of \$13,500,000.

The French Broad area is entirely without impoundments of the size proposed, and the addition of over 6000 acres of water surface should arouse considerable local use, particularly from the urban areas of Asheville, Brevard, Hendersonville, Canton, and Waynesville. Some use of the lakes by tourists is also anticipated, although the summer climate and scenery are the major tourist

attractions of the area. The anticipated recreation day use of the impoundments is estimated at about 300,000, which would produce benefits having a net value of \$8,600,000.

The construction of the French Broad project would help provide relief from the unemployment and underemployment existing in the area. This benefit, capitalized, is estimated to be \$9,500,000.

In addition to existing industrial land, Transylvania County has some 400 acres suitable for industrial sites which would be made essentially floodfree by operation of the system of reservoirs. Similarly, about 300 acres in Henderson County, in the area of the old Asheville-Hendersonville airport, would be protected. No monetary value has been placed on this potential conversion of agricultural to higher value industrial land.

The total capitalized benefits from the project amount to \$143,000,000, and the construction cost is estimated to be \$96,000,000. Taking into account the estimated operation and maintenance costs and an allowance for interest during construction, the project benefit-cost ratio is 1.4:1.0.

REPORT



Frontispiece - AGRICULTURAL LANDS INUNDATED DURING FLOOD OF OCTOBER 1964.

DEVELOPMENT OF THE WATER RESOURCES
OF THE FRENCH BROAD RIVER BASIN
IN NORTH CAROLINA

REPORT

In September and again in October of 1964 the people of the Upper French Broad River Basin were caught in the grip of their age-old problem--frequent and devastating floods. As far back as 1791 the history of this fertile basin has been one of damaging floods. A characteristic of this part of the Tennessee Valley is the fact that great floods can occur at any time during the year.

Following two damaging floods in August 1940, the Western North Carolina Flood Control Committee was formed with representatives from each county in the area. The committee sought aid from TVA, requesting that the flood situation be investigated to determine whether a feasible plan of flood protection could be developed. TVA made such investigations and in August 1942 issued a preliminary report indicating the feasibility of reducing floods at Asheville and portions of the French Broad River valley south of Asheville. Further investigations--interrupted during World War II--were completed in 1949; and a detailed project planning report was submitted to the President on January 12, 1950, with a statement that funds would be requested for construction at an appropriate time. No further action was taken on this plan because of the lack of sufficient local support.

In March 1961 the Western North Carolina Regional Planning Commission, through the North Carolina Department of Water Resources, requested TVA to undertake a program to develop and implement a plan for comprehensive unified resources development of the French Broad area as a basis for accelerating economic growth. Later that year these agencies and North Carolina State College, now the University of North Carolina at Raleigh, undertook an inventory of basic data and natural resources of the area. This work was completed and in May 1964 a 2-volume report was published entitled "Economic Development of the French Broad Area." About this same time an engineering study was initiated to determine the feasibility of comprehensive development of the water resources of the basin. Feasibility report

No. 0-6465, published in February 1965, presented a preliminary multiple-purpose plan for flood control and other purposes, which was found to be economically feasible. More detailed studies have been made during the last year, and this report presents a definite plan for multiple-purpose development of the water resources of the French Broad River Basin in North Carolina.

THE BASIN

The French Broad River Basin in North Carolina lies in the Southern Appalachian Mountain region of the state. At the Tennessee-North Carolina State line the river drains an area of 1664 square miles, which is comprised of parts of Transylvania, Haywood, Henderson, and Buncombe Counties, and all of Madison County (exhibit 1). It extends about 65 miles in a north-south direction and about 25 miles in an east-west direction. From the junction of the North and West Forks, above Rosman, the river flows north across the basin a distance of 116 miles before it crosses into Tennessee, 5 miles northwest of Hot Springs, North Carolina.

The basin is bounded by two great mountain ranges, the Great Smoky Mountains on the north and west and the Blue Ridge Mountains on the south and east. Originating in the very rugged mountains in the southern end of the basin, the French Broad River is formed by the junction of the East, Middle, West, and North Forks in the vicinity of Rosman and then flows north through a broad valley of fertile farm lands. The principal tributaries are Little River, Swannanoa River, Cane Creek, Mud Creek, Ivy Creek, and Laurel Creek on the east side and Davidson River, Mills River, Hominy Creek, Sandymush Creek, and Spring Creek on the west. About midway of its course in North Carolina the river flows through Asheville, the largest city in the basin.

Topography

The topography of the basin is extremely rugged around the rims and in the headwaters. Upstream from Asheville the slope of the main river is relatively flat, falling only about 160 feet in 60 miles. Downstream from Asheville there is a marked difference in gradient, the stream falling some 640 feet in the 40 miles between Asheville and Hot Springs. The valley floor is about 2000 feet above mean sea level, with

some peaks along the rim rising over 5000 feet. Mount Pisgah, on the western rim of the basin, is the highest, with a crest elevation of 5721. Approximately 74 percent of the area is now in forest cover.

THE REGION AND ITS ECONOMY

Because of the encircling mountain ranges and resources and socioeconomic interdependencies, the 5-county region of western North Carolina possesses most of the characteristics of a well-defined economic area. These counties have been designated by the State of North Carolina as a development district and by TVA, at the request of the North Carolina Department of Water Resources and the Western North Carolina Regional Planning Commission, as a region suitable for participation in TVA's tributary area development program.

The city of Asheville--center of western North Carolina's only officially designated metropolitan area--dominates the trade relations of the region and is the hub of its transportation network and cultural affairs. In addition, the Asheville metropolitan area contains more than three-fourths of the region's urban population, about 60 percent of the region's total employment, and the greatest concentration of services and other specialized activities usually associated with an urban center.

The principal urban satellites of the region--each a growing center of economic activity with specialized manufacturing and related enterprises--are Canton and Waynesville to the west of Asheville (Haywood County), and Hendersonville (Henderson County) and Brevard (Transylvania County) to the south. The growing interdependence of these centers is revealed by the rapid development of urban-industrial activities along the highways and railroads linking them, so that an almost continuous urban belt along Interstate Highways I-40, I-26, and U. S. 64 can be foreseen for 1980 or shortly thereafter.

The mountainous setting of the basin and pleasant year-round climate are the major attractions to the recreation industry. This setting is enhanced by the proximity of the Great Smoky Mountains National Park, several national forests, and the Blue Ridge Parkway, which draw visitors from the great metropolitan concentrations of eastern United States.

In the principal valley, along the tributary streams, and in the mountain coves, there are both profitable commercial farms supplying the urban population and small, often isolated, subsistence farms.

The principal industries are located on the main streams and along the major east-west and north-south rail lines. A trend toward the location of manufacturing activities along the periphery of the urban centers, as well as along the major transport arteries, is discernible.

Changing Forces in the Regional Economy

The Upper French Broad area is a region in transition. It is changing quite rapidly from a lagging region (in terms of education, employment, and income) to one that is being drawn into the industrial prosperity of the Piedmont Crescent and the cities lying along Interstate Highway I-85 in North and South Carolina.

In the past, low income levels have restricted the capabilities of residents to invest in private enterprises, public programs, and capital improvements. Partly because of low incomes and the resultant low investment in education, general educational levels are still considerably lower, especially in the mountain sections, than in the nation as a whole. As a result, fewer persons have the prerequisites for training and employment in the higher skills, and the locational advantages based on labor orientation have been largely restricted to industries which require low skills and pay comparatively low wages.

Agriculture--To a large extent the poverty and underemployment in the Upper French Broad region are the heritage of a system of low income agriculture. Too small and undercapitalized, many area farms do not produce enough for family subsistence and capital reinvestment. The farm problem is not confined solely, however, to the remote upland area and coves; there are pockets of low income farming in all parts of the region.

Between 4000 and 5000 persons under 65 years of age are relying mainly on farming for a living in the Upper French Broad area. Three thousand of these people farm hilly land unsuited to modern farming practices. In the 1950's 46 percent of those who were employed in agriculture left this sector for work elsewhere. Losses in farm employment will probably continue, but these losses will proceed from greatly reduced bases of farm labor supplies and will not induce so heavy an outmigration from the region as that experienced in recent decades.

The future of agriculture in the Upper French Broad area lies mainly in intensive farming of the fertile bottom lands along the rivers and creeks. While total agricultural employment will continue to decline, the intensive farming enterprises, such as poultry, livestock, dairying, specialty vegetables, and fruits and flowers, should continue to expand, increasing the total value of farm products and

the incomes of the remaining farm operators. This transition would be encouraged by flood relief to be provided by the plan of development along the fertile bottom lands of the French Broad River and the lower reaches of its tributaries above Asheville. In this way, competitive commercial agriculture would have an assured future in the valley.

For projection purposes, it has been assumed that there will be a continued shift of persons out of agriculture until 1980 (up to as much as 50 percent of the present rural farm population), although these persons may possibly remain in the region as rural-nonfarm residents. There are several possible destinations for those changing occupations. They may leave the area in search of work; they may retire within the area or become welfare recipients; or they may remain in the area as manufacturing or service employees. The net result should be a stronger, though smaller (in terms of employment), agricultural base.

Manufacturing--The people of the Upper French Broad area must look upon continued and accelerated development of manufacturing industries as a principal factor in economic growth and prosperity. Manufacturing industries in the area now account for about a third of the total employment. In terms of average annual wages per employee, however, the area is still below the national average. This is due to lower wages generally prevailing in the Southeast and especially to the area's high proportion of low-wage industries, such as textiles, apparel, and wood products. On the other hand, production workers in some of the industry groups which have achieved the greatest recent gains in employment in the area, such as industrial chemicals, paper and film specialties, electrical supplies, and precision parts for machinery, probably are among the highest paid production workers in manufacturing. However, these relatively high-wage industries still employ less than a fifth of the manufacturing employment total.

Studies of some of the major employers in the area show that during the 1950's the chemical industry, mainly synthetic fibers, gave rise to the greatest numerical increase of workers. However, greater percentage increases were registered by apparel, rubber products, and electrical machinery. One study estimates that over the period of 1960 to 1975 electrical machinery will register the greatest percentage gain, followed by apparel, synthetic fibers, furniture, and hosiery and knit goods.

Apparently, the Upper French Broad area has excellent prospects for further industrialization. Comparative advantages have existed for a long time for the location of industries using the area's forest and water resources and those

utilizing the low-skilled labor becoming available from farms. These advantages still exist and should induce some expansion of existing industries and the attraction of new types of manufacturing enterprises. However, all industries are reducing the proportion of low-skilled workers which they employ; and the best future prospects are for chemicals, electronics, and certain other high-wage industries which have a high capital-labor ratio and require workers with relatively high skill.

Nearly three-fourths of the present area employment in the manufacturing sector is in industries having relatively large water requirements. Most of these plants would not have located in the basin if they had not been afforded adequate water supplies of suitable quality. Barring radical and unforeseen changes in technology, material supply sources, or product demands, these industries should continue to be dominant in the area at least for the next two decades. The location of new plants in these industry classifications will be uncertain, however, until critical problems have been resolved regarding the quantity and quality of future water supplies and the controls that will be imposed upon the disposal of waste materials.

TVA projections of the labor force indicate that the availability of labor will be adequate for a growth in the 5-county manufacturing employment from about 32,000 in 1965 to between 40,000 and 45,000 in 1980. But such projections are in part contingent upon the availability of a sustained supply of skilled workers in appropriate occupations made possible by an expanded public education and training program, especially in vocational education.

In short, the rate at which desirable manufacturing jobs are created in the region will determine, to a significant extent, the rate at which net outmigration (which amounted to more than 10 percent of the population in the 1950's) is reduced in the years ahead. In general, people move because they are reacting to changing economic conditions. If the change in employment opportunities in the 5-county area continues to be favorable, and if the proposed water resources development project contributes to the maintenance of a favorable climate for industrial and related growth, it is quite possible that by 1980 the Upper French Broad Basin may attract more people from the outside than it loses to the rest of the country.

Recreation and Retirement--Within the large sector of employment known as the trades and services, the recreation-tourist trade would probably be the major contributor to growth in the future. Several studies of the region's economy show that the Upper French Broad Basin has an exceptional potential for recreation and



Figure 1 - INDUSTRIAL PLANTS AT PISGAH FOREST.



Figure 2 - INDUSTRIAL PLANTS AT ENKA.

that the area's natural assets, used intensively in the past, would continue to attract hundreds of thousands of traveling Americans. The area is accessible to a mass market--two-thirds of the nation's population is within a 2-day automobile trip and for most travelers on interstate highways it would be only a day's journey. This is important because the typical traveler nowadays arrives in a family group by automobile and stays in a motel. He tours large parts of the mountain area rapidly and rarely stays more than a day or two in the same location.

The Asheville area has long been a mecca for tourists. Many people in the area can still remember the Asheville "boom" in the 1920's which established it as one of the nation's top vacation areas. Wealthy individuals came to the region at that time by pullman car to stay in inns, hotels, or summer homes located in and around the city. The bulk of tourists who visit the region now come by automobile and are no longer primarily the well-to-do but are, rather, the middle-income group. Nonetheless, the new recreation market promises to surpass anything which has gone before. For example, in 1963 total travel expenditures in the area ran 266 percent over 1948 levels and were well ahead of statewide gains of 205 percent. The number of firms catering to this trade increased from 841 to 1279, a 52 percent increase. The total number employed in the recreation-serving industry was 5890.

Completion of Interstate Highways I-40 and I-26, extension of the Blue Ridge Parkway to the south, and construction of the Appalachian highway system in the area should further enhance the region's strategic position in regard to travel by automobile. However, it might also result in changing the focus of tourist objectives and permit easy bypassing of the area if facilities and attractions do not interest the tourists. Ingenuity and initiative are needed to devise and improve attractions that would help expand the tourist trade in the area as well as reduce its seasonality.

Retirement, like tourism and leisure-time activities, has developed into an important business calling for specialized facilities and environment. As in the case of the tourist trade, the Upper French Broad area has long had an attraction for retirees. It has a diversity of physical environment and community life which stands in sharp contrast to the monotony of many centers for retired people elsewhere. The economic potentialities of the "retirement business" therefore should not be underestimated for the future. In this respect, the management

of the proposed system of multiple-purpose lakes would be of considerable importance. In the provision of new recreational facilities for the growing number of transients, care also must be taken to preserve the traditional values of the region for the year-round resident and retiree. An increase in this business would have a major impact on employment in the trades and services, which has been lagging behind the growth of manufacturing, and increased local tax returns.

Land-Use Patterns--All the changes in the character of economic activity discussed above have important implications for the uses of land in the region.

If the economy is to grow on several fronts with employment in manufacturing leading the way, it is estimated that the population will have to reach a total by 1980 of about 290,000 in order to supply the projected demand for labor--almost 110,000 in 1980. Such a population level implies that net outmigration, while continuing during the 1960's, would stop and perhaps even reverse during the 1970's. By 1980 most rural residents would be either suburbanites or former farm workers who have shifted to nonfarm employment without moving their place of residence.

It is well known that residential and commercial-industrial development has been taking place along the fringes of the older urban centers and in the rapidly urbanizing strips connecting the towns. The decentralization of urban land uses can be expected to continue at an accelerated pace, with the gradual merging of suburban and rural nonfarm residential areas and the growth of industrial and commercial complexes along strategic transportation access points.

The following anticipated land-use changes are significant for the contemplated water resources development project:

1. In the Asheville area, the outward push of urban-industrial land uses will require readjustments in the older parts of the city. These adjustments will include rehabilitation of the central business district and the redevelopment of the so-called grey areas surrounding the downtown area. New growth is taking place along the old highway (U.S. 25) to Hendersonville and in the "T" around the intersection of I-40 and I-26.
2. An important node is almost certain to develop in the vicinity of the Asheville airport, midway between that city and Hendersonville, now served by Delta, Eastern, and Piedmont airlines. Here access to the interstate highway, proximity to air transportation, availability of process water, utilities, and the myriad services of a metropolitan location can be combined into an industrial-commercial park "package" attractive to private investors.

3. Other areas of potential industrialization have been identified along the banks of the French Broad River and U. S. Highway 64 above Horse Shoe, North Carolina, as well as along the alignment of I-26.

Much of the region's present residential-commercial-industrial development has taken place along an internal highway network built a generation or so ago. Major changes in this pattern can be expected in response to such external developments as the interstate and Appalachian highways which would "open up" the Upper French Broad Basin to hitherto distant markets such as Knoxville, Chattanooga, and the Tri-Cities of northeastern Tennessee, as well as to the booming cities along the Piedmont Highway, I-85. It is easy to foresee therefore that by 1980 the entire stretch between Asheville and Hendersonville and between Black Mountain and Waynesville (along the I-26 and I-40 belts respectively), would be given over to intensive industrial urban land uses.

HYDROLOGY AND METEOROLOGY

Rainfall

Precipitation varies considerably over the basin. In the southern mountainous region the 25-year annual mean rainfall is about 75 inches; while at the U. S. Weather Bureau station at Asheville the 90-year annual mean rainfall is only about 38 inches. September, October, and November are usually the low rainfall months and March, July, and August are the highest. The latter condition emphasizes the fact that the entire area is subject to intense rainstorms having tropical hurricane characteristics. In addition to these storms over large areas, heavy summer thunderstorms tend to strike smaller areas.

Intense rainstorms have occurred in recent years in the upper end of the basin. For example, during a 10-day storm period, September 27 to October 6, 1964, a total of 35.44 inches was recorded. During this storm a maximum precipitation of 13.10 inches was recorded in a 24-hour period. At the Rosman gage 28.86 inches was recorded for the month of August 1961.

Streamflow

Streamflow data have been recorded in the basin at some 23 gages.

A list of 14 selected gages, their locations, and the number of years of record follows:

<u>Stream Gage</u>	<u>Drainage Area, Square Miles</u>	<u>Years of Gage Record</u>
French Broad River - Marshall	1332	23
- Asheville	945	70
- Bent Creek	676	32
- Blantyre	296	45
- Rosman	67.9	31
Big Laurel Creek - Near Stackhouse	126	32
Ivy Creek - Near Marshall	158	32
Swannanoa River - Biltmore	130	38
Beetree Creek - Near Swannanoa	5.46	39
Hominy Creek - Candler	79.8	23
Mills River - Near Mills River	66.7	34
South Fork Mills River - Pink Beds	9.99	24
Davidson River - Near Brevard	40.4	45
Little River - Above High Falls	26.8	3

Pertinent data from some representative gages follows:

Stream Gage	Discharges						Avg Annual Discharge
	Maximum			Minimum			
	Date		CFS	Date		CFS	CFS
French Broad River:							
Marshall	Jul	1916	115,000	Sep	1954	193	2355
Asheville	Jul	1916	110,000	Sep	1925	239	2065
Bent Creek	Jul	1916	90,000	Oct	1954	230	1634
Blantyre	Jul	1916	50,700	Oct	1954	119	949
Rosman	Oct	1964	13,500	Jan	1940	23	232
Swannanoa River:							
Biltmore	Apr	1791	40,000	Oct	1941	1	157
Hominy Creek:							
Candler	Aug 30,	1940	13,100	Sep	1953	13	91
Mills River:							
Mills River	Aug 30,	1940	13,400	Dec	1943	16	160
Davidson River:							
Brevard	Jun	1876	8,500	Oct	1954	13	127

Past Floods

The most complete record of flooding in the French Broad Basin is at Asheville, where data on major floods extend back to 1791. Although the formal record began in September 1895, newspapers and other historic documents provide some knowledge of earlier great floods. The table on the following page lists all known floods which exceeded bankful stages at Asheville, and exhibit 2 shows the flood history plotted chronologically. The largest flood of record at Asheville occurred in July 1916 and was the most damaging ever to occur basinwide. The second most damaging flood occurred in October 1964 and produced a record stage at Rosman.

The record at Asheville shows that seven of the highest ten floods have occurred in the months of June, July, and August, largely as a result of hurricanes from the southeast. Flooding is frequent during these months, with more than one damaging flood a year expected during the crop season along the lower reaches of the major tributaries. Detailed reports of many of the more recent floods have been prepared by the Hydraulic Data Branch.

Natural and regulated flood hydrographs at the Rosman, Blantyre, Bent Creek, and Asheville gages are shown on exhibit 3.

NEEDS, OBJECTIVES, AND PLANNING CRITERIA

This study has been directed toward preparing a plan of development for full utilization of the water resources of the French Broad River Basin in North Carolina, as part of an overall plan to achieve the economic potential of the region and to enhance the area's aesthetic and cultural values. The plan is conceived so that the proposed development of the basin's water resources would assist rather than interfere with the changes in land use and human activities that are occurring and are likely to take place in the foreseeable future. The guiding objective of the engineering study has been to develop each dam and reservoir site to its fullest extent compatible with topographic, geologic, and streamflow limitations and cost--keeping in mind that water reserved now for potential water supply and water quality control will be of inestimable value in future years.

FRENCH BROAD RIVER AT ASHEVILLE, NORTH CAROLINA
FLOOD CREST ELEVATIONS AND DISCHARGES ABOVE BANKFULL STAGE

1791-1965

<u>Date of Crest</u>		<u>Gage Height - Feet</u>		<u>Peak Discharge</u>	
		<u>Stage</u>	<u>Elevation</u>	<u>Amount, CFS</u>	<u>CFS Per Sq. Mile</u>
Apr	1791	(a)			
Aug	1796	14	1964		
	1810	13	1963		
May	1845	14	1964		
Aug	1850	13	1963		
Aug	1852	15	1965		
Feb	1875	9	1959		
Jun	17, 1876	18	1968		
Oct	17, 1879	9	1959		
Jun	1892	10	1960		
Sep	13, 1893	9	1959		
Jul	8, 1896	8.8	1959.1	21,600	23
Mar	15, 1899	10.5	1960.8	26,600	28
Mar	19, 1899	10.4	1960.7	26,200	28
Mar	26, 1901	8.6	1958.6	18,900	20
May	22, 1901	11.1	1961.4	29,300	31
Aug	6, 1901	8.0	1958.3	16,700	18
Aug	17, 1901	8.0	1958.3	16,700	18
Dec	16, 1901	10.7	1961.0	26,900	28
Dec	29, 1901	9.5	1959.8	22,400	24
Feb	28, 1902	11.6	1961.9	33,900	36
Mar	23, 1903	8.0	1958.3	19,000	20
Jul	12, 1905	9.0	1959.3	23,000	24
Jan	23, 1906	9.4	1959.7	25,800	27
Jun	4, 1909	8.1	1958.4	19,200	20
Aug	31, 1910	11.2	1961.5	30,300	32
Mar	14, 1913	8.7	1959.0	21,200	22
Oct	16, 1914	8.3	1958.6	19,900	21
Jul	11, 1916	9.8	1960.1	25,100	27
Jul	16, 1916	23.1	1973.4	110,000	116
Oct	30, 1918	9.0	1959.3	22,100	23
Dec	23, 1918	10.0	1960.3	25,600	27
Apr	2, 1920	8.1	1958.4	19,000	20
Aug	16, 1928	13.27	1963.6	42,700	45
Oct	16, 1936	8.20	1958.5	19,200	20
Aug	14, 1940	11.65	1961.9	31,800	34
Aug	30, 1940	12.15	1962.4	34,800	37
May	21, 1942	8.93	1959.2	20,900	22
Dec	30, 1942	8.10	1958.4	18,000	19
Jun	17, 1949	9.00	1959.3	20,100	21
Aug	28, 1949	8.55	1958.8	18,500	20
Dec	7, 1950	8.03	1958.3	16,400	17
Jan	23, 1954	8.07	1958.4	16,500	17
Apr	5, 1957	10.30	1960.6	24,200	26
Aug	25, 1961	9.01	1959.3	19,000	20
Mar	13, 1963	8.62	1958.9	17,600	19
Oct	5, 1964	12.75	1963.0	36,200	38
Mar	26, 1965	8.07	1958.4	15,700	17

(a) Stage unknown but was probably about equal to that of July 16, 1916.

This table includes all known floods above bankfull stage of 8 feet at the Asheville gage, located just downstream from Pearson Bridge, mile 145.75. Drainage area is 945 square miles.

Flood Control

Because of the great possibility of disastrous floods, the major objective of the plan of development is to reduce potential flooding to the point where there would be a relatively minor effect on agriculture and urban development.

Agriculture--About 75 percent of the farms in the basin are on steep, hilly land, mountain slopes, and coves. The remaining farms are on the inter-mountainous plateaus and along the low-lying fertile flood plains. The flood plain farms produce principally beef, dairy, and horticultural products. Beef and dairy products tend to remain in the local market, while horticultural products are generally shipped to other areas.

In some years, these areas experience damaging floods two or three times during the crop season, which in this region extends from April through November. Floods have caused loss of crops and have brought bankruptcy to some farmers who have ventured into horticultural production. Losses such as these have discouraged more widespread planting of specialty crops.

Climatic and soil conditions in the basin are favorable for midsummer and late summer vegetable production. These are periods when quality fresh vegetables are usually in short supply. Expanded horticultural production in the basin would favorably affect consumers by providing quality fresh market products during the season of low production in other major producing areas. Although only limited acres of flowers are grown along the French Broad River and some of its tributaries, they produce considerable income and seasonal employment in the areas south of Asheville.

Urban--There are currently some eighteen areas of urban development in the basin which are subject to flooding, with a total average annual potential damage of about \$1,600,000. The major urban damages occur in the Asheville area, which accounts for 80 percent of the total damage figure. A levee at Asheville would be built high enough to afford protection against a flood equal to the regulated flood of record. This represents a high degree of protection since the 1916 flood can be characterized as approaching a maximum probable flood.

Roads and Bridges--Under existing conditions extensive flooding of U. S. and state roads and bridges and the Southern railroad occurs almost annually. Many miles of roads, railroads, and bridges outside urban areas are also subject to flood damages. With the 74 miles of channel improvements and 14 dams, much of this damage would be averted.



Figure 3 - ROSMAN, SHOWING LIMITS OF FLOOD OF RECORD, OCTOBER 1964.



Figure 4 - BREVARD, SHOWING LIMITS OF FLOOD OF RECORD, JULY 1916.



Figure 5 - HENDERSONVILLE, SHOWING LIMITS OF FLOOD OF RECORD, JULY 1916.



Figure 6 - OCTOBER 1964 FLOOD AT ROSMAN AND PENROSE BRIDGE.

Upper photo shows high water in town of Rosman, from Southern Railway tracks looking toward French Broad River. Note high water marks on buildings. Lower photo shows French Broad River at Penrose Bridge, mile 186.8. Note approach to bridge and Southern Railway tracks inundated.



Figure 7 - OCTOBER 1964 FLOOD AT BLANTYRE AND MCLEAN BRIDGES.

Upper photo shows Blantyre Bridge, across French Broad River at mile 183.7, and approaches inundated. Note also expanse of cropland inundated on each side of river. Lower photo shows French Broad River looking northeast from the vicinity of the sewage treatment plant at Brevard, N. C., showing flooding of bottom lands.



Figure 8 - OCTOBER 1964 FLOOD AT HENDERSONVILLE.



Figure 9 - OCTOBER 1964 FLOOD AT BUTLER BRIDGE.

Photo taken from near mouth of Mud Creek looking north. Note left bank approach to Butler Bridge inundated. Asheville-Hendersonville airport can be seen at upper left.



Figure 10 - OCTOBER 1964 FLOOD AT BILTMORE.

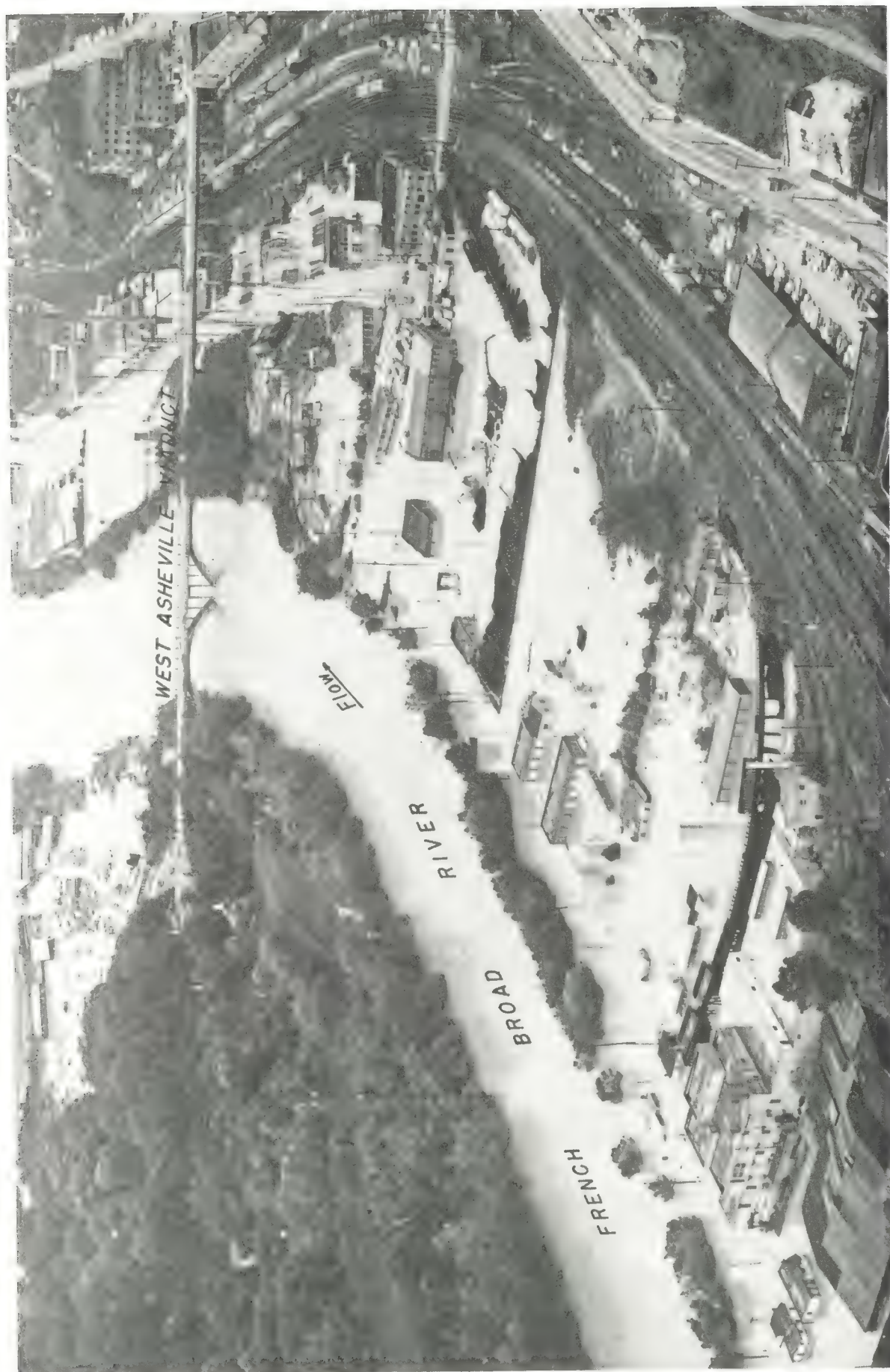


Figure 11 - FRENCH BROAD RIVER AT ASHEVILLE, LOOKING DOWNSTREAM. FLOOD OF OCTOBER 1964.



Figure 12 - OCTOBER 1964 FLOOD AT MARSHALL.

Water Supply

There are eleven municipal water supply systems in the four counties covered in this report. Six of these systems take advantage of the rugged topography of the area by using catchment basins on headwater tributaries of the French Broad River. These sources of supply now require a minimum amount of treatment since the runoff is from uninhabited lands covered with dense forests. However, treatment of all water supplies for domestic use, irrespective of source, probably will be required in the near future. Wells are used as a source at Rosman, while five springs serve Laurel Park. The remaining supplies are taken from streams.

The inventory report, entitled "Economic Development of the Upper French Broad Area," dated May 1964, emphasizes the fact that additional sources of water would be required in the Upper French Broad region as the area develops economically. Several of the impoundments planned would be located close to potential industrial sites. These reservoirs would have storage volumes reserved for providing new water supplies and for expanding present facilities. For example, the Mills River Reservoir would provide 11,500 acre-feet for present and future use for both Hendersonville and Asheville metropolitan areas. It is estimated that this amount would be adequate to meet their needs through the year 2070 for both municipal and industrial use. Storage also would be provided in Mud Creek, Swannanoa, Devils Fork, and Ivy Creek Reservoirs for future industrial growth. Industrial sites have been identified near these reservoirs; therefore it is felt that some supply should be provided if the streams near these sites cannot furnish an adequate supply of water without impoundment.

A regional water supply system for Transylvania, Buncombe, and Henderson Counties appears to be a possible developing need.

Water Quality Control

The existing industries in the French Broad River Basin were attracted to the area partly because of the abundance of clean, cold, clear water flowing out of the mountains. As the industries have grown and as the population has increased, many stream reaches have become polluted. Often the color is objectionable and the dissolved oxygen content is so low that fish cannot survive. In such stream reaches, there is no waste assimilative capacity left for new industries to use.

Industries in the city of Asheville add waste loads to the stream equivalent to 114,000 people. Reductions are in prospect, however, as a result of corrective steps now being taken by the industries and the metropolitan district.

For many years the main stem of the French Broad River between Davidson River and Mud Creek has been one of the most polluted streams in the South. One large industrial plant discharges untreated waste into this reach of the river. Presently the waste from this plant is highly colored and has a biochemical oxygen demand equivalent to the waste load from a population of 360,000 people. Under present conditions during the low-flow months it is not uncommon for the dissolved oxygen level in several miles of the river between Davidson River and Mud Creek to be below 4 mg/l (milligrams per liter), dropping to zero at the low point of the oxygen sag. This reach of the river is presently classified by the North Carolina State Stream Sanitation Committee as class E (1 mg/l of dissolved oxygen required at the low point of the sag), but water quality is now below even class E specifications. This dissolved oxygen deficiency results from the discharge of untreated organic wastes in quantities far exceeding the stream's capacity to assimilate such wastes.

The North Carolina State Stream Sanitation Committee has requested the industry primarily responsible for the major pollution problem in the Davidson River area to provide pollution control, equivalent to secondary waste treatment. The industry is presently making inplant changes and constructing treatment facilities equivalent to secondary treatment in compliance with the committee's request. For some years after the facilities are placed into operation, the minimum dissolved oxygen level in the stream downstream from river mile 190.6 (mouth of the Davidson River) during periods of low flow would be about 4 mg/l, well above the minimum level for class E specifications. As time passes and treated waste loads increase due to normal industrial and population growth, dissolved oxygen concentrations should recede to lower levels.

By providing water quality control storage in the proposed reservoir system to augment streamflow, the stream classification could be raised from the present class E to a more desirable classification of C.¹ A minimum streamflow of 260 cfs would be required at river mile 190.6 to maintain class C water quality

1. Classification C is defined as water satisfactory for fishing and fish and wildlife propagation; classification E, water satisfactory for navigation and disposal of sewage or wastes, but disposal not to be to the extent of causing offensive conditions from floating solids, settleable solids, oils, sludge deposits, or odor-producing substances.

in this reach through the year 2070.¹ A total of 26,000 acre-feet of upstream storage would be required to maintain this flow. This volume of storage would be provided in the East Fork and North Fork impoundments and would be guaranteed even during a recurrence of the driest period of record, and records extend back to 1920.

A second phase of the water quality control problem concerns plant nutrients. Instream concentrations of nitrogen and phosphorus from sewage effluents and farm drainage must be reduced by waste treatment, where feasible, and by streamflow regulation to help avoid nuisance-level growths of benthic weeds in the French Broad River downstream from Asheville and of algae in Douglas Reservoir. The aquatic plant growing season generally is May through September; therefore provisions would be made for releasing water during this period. Studies to determine the need for streamflow regulation for plant nutrient control indicate that the 30-day, 10-year minimum streamflow should be used for planning purposes. Below the mouth of Ivy Creek this flow is about 530 cfs.¹ Project planning studies show that the minimum daily flow of about 300 cfs at this point could be increased to a dependable sustained minimum flow of 860 cfs. With the planned reservoirs, the increased flow could be maintained even if another dry period such as that which occurred in 1954 should recur after the system goes into operation.

Recreation

For many years the Asheville-Hendersonville-Brevard area was one of the prime vacation regions in the Southeast, largely because of the delightful summer climate and the beautiful mountain scenery. Mt. Mitchell, elevation 6684, the highest point east of the Mississippi River, is located only about 25 miles northeast of Asheville. There are other nationally known attractions located nearby, such as the Biltmore estate and the Cradle of Forestry. Also this is the eastern approach to the Great Smoky Mountains National Park.

The proposed reservoirs would help to meet the local demand for water-oriented recreation while at the same time enhancing the area as a tourist destination by adding water-oriented recreation opportunities. While the French Broad Basin possesses many desirable recreation features, the area is generally without impoundments of sufficient size to accommodate various types of water-oriented recreation activities. It is expected that eleven of the proposed reservoirs located in strategic

1. Tennessee Valley Authority, Division of Health and Safety, Water Quality Branch, "Streamflow Regulation for Water Quality Control, Upper French Broad River Basin," September 1966.

areas would generate considerable use by residents of the watershed. The relationship of these impoundments to the highway system places them within minutes of one or more urbanized areas.

In an effort to enhance the recreation potential of the reservoirs, drawdown during the recreation season, April 1 to Labor Day, would be limited to no more than about 5 feet, even under the most severe dry conditions. In an effort to meet the needs of anticipated recreation use of the projects, provisions would be made for boat-launching ramps, parking facilities, picnic areas, sanitary facilities, and potable water at appropriate locations around the shorelines.

Fish and Wildlife

This plan of development was coordinated at all stages with the North Carolina Wildlife Resources Commission. The commission was asked to furnish data on fish and wildlife resources and has given opinions and recommendations on effects of the various units of the project.

One objective in planning the impoundments was to interfere as little as possible with existing water courses designated by the commission as trout streams. This would require means to ensure that water discharged from the reservoirs would have low temperature and high dissolved oxygen. Other items involving protection and development of the fishery to be considered include public access, channel improvement, upstream fish barriers, and reservoir operations.

Industrial Sites

The importance of preserving existing and creating new potential industrial sites in the French Broad River valley upstream from Asheville was early recognized as one of the major objectives of water control planning, since the inventory report¹ identified only twenty-nine prime industrial sites in the entire area. Protection from flooding, provision of an ample supply of clean water, and ready accessibility are the key considerations to developing the industry potential. There are some 400 acres in Transylvania County and about 300 acres in the area of the old Asheville-Hendersonville airport that would be so improved.

1. North Carolina State-Tennessee Valley Authority, "Economic Development of the Upper French Broad Area," volume 1, May 1964.

Power

The hydro potential of the French Broad River and its tributaries upstream from Asheville is extremely limited and is economically unattractive as a source of future power supply.

SELECTED PLAN OF DEVELOPMENT

During the course of this investigation more than fifty dam sites have been studied and roughly evaluated as components in different combinations of a system. The plan considered best in the preliminary stages was presented in the feasibility report No. 0-6465 dated February 1965. This plan called for eleven impoundments, three detention basins, and some 77 miles of channel improvements, together with levees to protect the cities of Rosman and Asheville.

The plan described in that feasibility report was accepted in general by representatives of the area, but with the request that consideration be given to possible alternatives for the Brevard and Little River units in Transylvania County. This was done as detailed studies proceeded, with the result that alternatives to the Brevard Dam site were found on the North Fork, East Fork, and West Fork that would be economically feasible. With this substitution the levee around Rosman would not be necessary. However, no suitable alternative was found for the Little River unit.

Other modifications of the preliminary plan consist of the elimination of an impoundment on Turkey Creek and of the detention basin on the Davidson River, conversion of the detention basins on Ivy and Hooper Creeks to impoundments, and changing of the Swannanoa unit temporarily from an impoundment to a detention basin. The latter is so planned that within 5 years after construction the basin would be converted to an impoundment. This time lag would enable Warren Wilson College to make relocation adjustments without adversely affecting their student work program.

As finally planned the water control system consists of 14 dams, which would control the runoff from 583 square miles of drainage area; 58 miles of channel enlargement; 16 miles of bank clearing along the channel; and a levee along 1.4 miles of the Asheville waterfront. The location of each of the units in the selected plan of development is shown on exhibit 1.

FOUNDATION EXPLORATIONS

Two salient facts stand out as a result of the foundation explorations:

(1) all of the rocks are quite strong when unweathered and generally are well suited to support any type of dam and (2) for earth- and rock-fill dams, the soils explorations generally indicate that suitable foundations can be prepared at a reasonable cost and that sufficient fill material is available within economical hauling distances of the sites.

Core Drilling

Core drilling of dam sites in the French Broad River Basin has been done in two separate programs, 20 years apart. The major part of the drilling at the Little, Mills, and Swannanoa Dam sites was done in 1944 and 1945; while the remaining dam sites¹ were drilled in 1964 and 1965. The drilling programs were designed to determine the thickness of overburden, the amount of weathered rock, and the depth to sound rock along (1) the proposed axes for the dams, (2) the crest and centerline of the proposed spillways, and (3) the centerline of the conduits or tunnels. In general, only one range of rather widely spaced holes was drilled for each feature at each site. During the more recent program, core drilling was supplemented by seismic determinations of top of rock between drill holes at some sites.

Geology

Most of the Upper French Broad drainage area is underlain by metamorphosed rocks in which the original characteristics have been modified to a large degree by increased temperature and pressure during earlier periods of deep burial in the crust of the earth. These rocks are the once deeply buried "roots" of the ancient Appalachian Mountain system. They have been squeezed and folded and are broken by large-scale faults. Blocks of rock thousands of feet thick and miles wide have been moved several miles from their original position along some of the faults.

1. Drilling permits were unobtainable at the Mud Creek Dam site; tight scheduling made it necessary to use field examination and seismic surveys at the Ivy Creek Dam site.

Various kinds of gneisses and schists are the most widespread types of rock. The gneisses are characterized by alternating, irregular, light- and dark-colored, discontinuous bands having different mineral composition. The schists are banded on a much smaller scale; the individual bands are only a small fraction of an inch thick and are not readily apparent.

A distinctive narrow belt, 1 or 2 miles wide, known as the Brevard zone, is recognizable throughout the area for a distance of more than 100 miles. This zone, which contains several rock types, including metamorphosed limestone and other low-rank metasedimentary rocks, underlies the town of Brevard, North Carolina, and passes about 8 miles southeast of Asheville, North Carolina. Its trend is about 40 degrees east of north, roughly parallel to the general outcrop pattern of the area. A major thrust fault is believed to separate this zone from rocks to the southeast.

A 6- to 10-mile-wide belt of foliated granite-like rocks borders the Brevard belt on its southeast side. Farther southeast, these rocks in turn are bordered by schists and gneisses within which occur large areas of weakly foliated granitic rocks. Schists, gneisses, and weakly foliated granitic rocks make up most of a 25-mile-wide belt which borders the Brevard zone on the northwest side. In the northern part of the watershed, this western belt of gneisses and schists interfingers with several types of foliated rocks known as the Max Patch granite.

Exhibit 5 is a map showing generalized geology of the area.

Five dam sites--East Fork, Little, Devils Fork, Clear, and Hooper--are located wholly on the sheared, gneissic Henderson granite. The West Fork, Mills, South Hominy, and Swannanoa Dam sites are located on the high-rank gneisses and schists of the Carolina formation. The North Fork, Boylston, and Cane Creek sites are located on low-rank metamorphic rocks of the Brevard zone.

While high mountains of barren rock abound in the region, moisture conditions suitable for rock decay exist in the lower hills adjacent to the streams where erosion is not rapid enough to remove the moist blanket of earth. Owing to the low gradients of many of the streams in the region, mechanical erosion and abrasion have been retarded and rock decay has proceeded more rapidly than erosion. The result is the development of a blanket of decomposed and leached rock, known as "saprolite," overlying and gradually grading into sound rock. The depth of saprolite may vary from a foot or less in areas adjacent to the stream channels to over 100 feet on the hill crests or in saddles in the higher ridges.

At the Mills, Cane, Devils Fork, Clear, Hooper, and Mud sites decomposed rock, or saprolite, occurs in serious proportions below the riverbed. At the Mills and Cane sites cutoff trenches would be excavated to sound rock, while at Devils Fork, Clear, Hooper, and Mud an impervious blanket would be placed at the base of the upstream slope of the dams. At all other sites, essentially sound rock occurs at river level and the top of sound rock rises into the abutments. The upper portions of all abutments are covered by a thick layer of saprolitic material which slowly grades into unweathered rock at depth. For this reason, good, sound rock normally is not to be found at spillway levels and some protection will have to be provided against erosion of the spillway structures.

Soils

A soils investigation program adequate for project planning purposes has been conducted at the dam sites. Generally, enough holes were put down to determine (1) bearing capacities of the soils, (2) the location and extent of any weak foundation material that should be removed, (3) side slopes for dams, and (4) the location and amount of available borrow material. There is a shortage of good material for rolled earth fill in the immediate site areas of Ivy, East Fork, and North Fork Dams. Earth- and rock-fill sections have been selected for these sites.

The results of the investigation indicate that most of the flood plains at the sites are overlain with alluvium, inorganic silts, silty sands, and gravelly lean clays.

STRUCTURES

Layouts of the structures for the different units of the project, together with summaries of the principal features of each, are shown in the exhibits and tables at the end of the text. General considerations of the different units are discussed in this section of the report.

Dams

The locations of the dams are shown in exhibit 1. The individual structures and the reservoirs, or detention basins, are shown in the exhibits for the different units. Two of the dams, West Fork and Swannanoa, would be detention structures only. However, the Swannanoa unit would be built initially so that it could be converted to a permanent impoundment 5 years after completion of construction. The remaining

twelve dams would be multiple-purpose structures with provision for one or more purposes, such as flood control, water quality control, water supply, recreation, and fish and wildlife. The North Fork, East Fork, and Ivy units would utilize earth- and rock-fill dams; Swannanoa Dam would be concrete; and the other ten would be constructed of rolled earth fill, generally having 3 to 1 slopes upstream, a top width of 20 feet, and a downstream slope of 3 to 1. Ivy Dam (exhibit Q4) would be the highest, at 214 feet; while Devils Fork (exhibit J5) would be the lowest, at 43 feet; and length of structures ranges between 490 feet for West Fork Dam (exhibit A5) and 2400 feet for Mills Dam (exhibit G5).

With the exception of the West Fork unit, plans call for the spillways to operate no more often than once in 100 years on the average. With the substitution of the alternative East, North, and West Forks Dams for the Brevard unit of the feasibility study, it became desirable to add more flood control storage at West Fork. This was accomplished by raising the spillway crest to the maximum physical limitation feasible. This level corresponds to about a 500-year frequency of use, and would increase the flood control storage from 4.8 inches on that drainage area to 5.7 inches. The amount of controlled storage for all units varies from 1.7 to 5.7 inches of runoff from the individual drainage areas. For floods having an estimated frequency of occurrence greater than once in 100 years, additional control would be provided through temporary buildup of the surcharge volume of the reservoirs above the spillway crest. These volumes of runoff range from 3.4 to 12.4 inches from the drainage areas.

With the exception of the Devils Fork and Swannanoa units, all spillways would have broad-crested concrete weirs as controls, with concrete paving extending downstream far enough to ensure the safety of the dams.

Current studies indicate that problems involving water temperature and dissolved oxygen in the French Broad River could be adequately handled by the use of low-level outlets. Additionally, it is expected that the use of Howell-Bunger valves in the low-level outlet system will assure satisfactory amounts of dissolved oxygen in the discharged water.

Wherever topographic and geologic conditions are favorable, pressure tunnels have been planned and the valves located at the downstream ends where they could discharge freely into the atmosphere. Where tunnels could not be used and conduits would be placed in the dams, the valves have been located in the valve towers.

The conduits through earth-fill or earth- and rock-fill dams would be sized to flow partially full so that pressure would not build up within them. Continuing investigations may indicate that such an arrangement may not permit sufficient absorption of oxygen from the operation of the Howell-Bunger valves. If that is the case, the valves would have to be placed at the downstream end of the conduits, made safe for pressure operation.

As now planned, releases from East Fork, North Fork, South Hominy, Mills, Ivy, and Little impoundments would be made through Howell-Bunger valves located on the downstream end of tunnels. Releases from Mud, Devils Fork, Clear, Cane, and Hooper impoundments would be made by Howell-Bunger valves located in the valve towers, discharging into the upstream end of a nonpressure conduit.

The Boylston unit would be designed with the normal flow passing through a notch, or weir, located in the center of the spillway. Provisions for vector control drawdown would be incorporated into the conduit provided for diversion during construction. Levels above the normal maximum would occur only during flood control operations.

It was estimated that the annual sedimentation load would vary from about 300 tons per square mile per year for the headwater reservoirs to about 1000 tons per square mile per year for the Swannanoa unit. An estimate also was made of the distribution of trapped sediment within the reservoirs after 100 years of accumulation and its effect on the multiple-purpose pool storage and the detention capacities. Reductions in storage volumes up to the normal maximum pool level would vary from 3 to 30 percent, depending upon the silt load and reservoir volumes. Flood detention capacities were increased to compensate for the anticipated 100-year sediment accumulation.

Asheville Levee

The industrial area on the right flood plain along the Asheville waterfront would be protected by a levee. It would extend from the Southern Railway bridge, at river mile 147.2, upstream and tie into the railroad yard below the mouth of the Swannanoa River, at mile 148.6, a total distance of 1.4 miles.

At the upstream end of the levee where there is sufficient space, an earth-fill dike would be used; but where existing structures are close to the river, a reinforced concrete floodwall would be built. The top elevation would be 1 foot

above the level expected from a flood equivalent to the 1916 flood as regulated by the water control system. This means that the elevation of the top of the levee would decrease slightly in the downstream portion. The earth section should have side slopes 2.5 horizontally to 1 vertically, with riprap on the riverside, and a 10-foot top width except where Riverside Drive is carried on top (exhibit S1). The concrete section would be a reinforced cantilever section poured on a lean concrete base which would be placed on bedrock. The earth and concrete sections would have positive cutoffs sealed to top of rock, as determined by foundation explorations. Soils tests indicate that suitable borrow material could be obtained from an area just northeast of the Southern railroad roundhouse.

Channel Improvement

Channel excavation is planned to begin at mile 165.2 in the French Broad River and extend 42.6 miles upstream to mile 207.8. Another 15 miles of channel work would extend along the major tributaries. At the downstream end the main stem channel would be 220 feet wide, narrowing to 75 feet upstream as the uncontrolled drainage area decreases. Side slopes would be 1.5 to 1.0. Excavated material would be spread uniformly to a depth of about 3 feet on land on which TVA would secure easements, and would be seeded promptly in order to minimize erosion.

Upstream from mile 207.8 the banks would be selectively cleared both to meet the hydraulic requirements for containing the 5-year crop season flood and to leave as much streamside shade as possible. The same criteria would be used in tributary channel work. To prevent regrowth, stumps left intact would be painted with herbicides.

Soundings indicate that little rock would need to be removed. Thus, the greater part of the excavation would result from channel widening from one side except on the Swannanoa River. Here, in an intensively developed area, channel improvement could be achieved more economically by deepening. Generally, the stream bottoms would be modified as little as possible leaving the pool-riffle sequence as nearly intact as hydraulics would permit. Uniform bottom gradient would be avoided, and a conscious effort should be made to keep the pools intact. It is expected that depth of base flow in the stream channels would not be substantially different from present depths.

A diagram and tabulation of channel capacities for existing and improved conditions are shown on exhibit R3.

RESERVOIRS AND RESERVOIR ADJUSTMENTS

Data concerning the detention basins and impoundments are shown in table 1 and the reservoir and detention basin maps are shown as exhibit drawings. It is estimated that approximately 595 families would have to be relocated.

The purchase of all lands below the maximum probable flood elevation is contemplated, together with additional land that may be required for reservoir operation and maintenance, to avoid unreasonable severance damage, to avoid undue expense in providing road access to isolated tracts, and to provide for maximum development and use of the reservoirs for purposes of public benefit.

It is recommended that the reservoirs be cleared to a level 1 foot above normal maximum pool. By so doing, the shorelines would be made more attractive for recreational use, while at the same time the required volumes for flood control would be maintained. In each instance this level would be well below the spillway crest. Experience after completion of the project may show the desirability of clearing to other levels in some reservoirs, based on the resistance of trees to frequency and duration of flooding in that particular location.

In most cases, normal reservoir preparation would include a nominal amount of road and bridge building and utility relocations. However, it will be necessary to relocate the 27-inch-diameter trunk sewer which extends the entire length of the Swannanoa detention basin. Present plans are to intercept this line, construct a pumping station, pump the sewage southward over the ridge, and run the line down the U. S. Highway 70 right-of-way. In Clear and Little Reservoirs there are 8-inch-diameter natural gas lines which would have to be relocated.

Hendersonville, North Carolina, has two cast-iron, water supply lines that run through the Mills River Reservoir. It will be necessary to relocate 8200 feet of 16-inch-diameter, cast-iron line and 24,600 feet of 20-inch-diameter, cast-iron line.

All highway relocations would be based on the principle that the new roads should provide transportation service equivalent to that furnished by the existing system prior to construction of the project. The level to which adjustments would be made would be generally less than the 50-year frequency of flooding. However in some instances the cost would be about the same regardless of the level of relocation. In such cases the roads would be built to the spillway crest, or the 100-year frequency.

Vector Control

Although vector control is not expected to be a major problem in the Upper French Broad River Basin, control measures, such as clearing, low stumping of certain areas, and marginal drainage, would be incorporated in the initial construction of the reservoirs. Where economically feasible, the shallow areas with a high potential for mosquito production would be eliminated by deepening and filling. Following impoundage, vector control would be accomplished through shoreline maintenance and reservoir recession if required.

ESTIMATED COST

Construction Cost

The total estimated construction cost of this plan of development, consisting of 12 dams and reservoirs, 2 detention basins, an estimated 74 miles of bank clearing and channel improvements, and a levee at Asheville, amounts to \$96,000,000. A summary cost estimate appears on table 3.

The estimated cost is based on the construction planning schedule shown in exhibit 6. It assumes that equipment would be moved from one site to another in the most efficient sequence, with four or more units being built at the same time. All costs are based on estimates of wages and prices projected to fiscal year 1972, the midpoint in the construction period as now scheduled. The costs are summarized as follows:

Dams and reservoirs	\$81,400,000
Channel improvements	8,000,000
Asheville levee	<u>6,600,000</u>
Total Construction Cost	\$96,000,000

It has been assumed that any lands now owned by the U. S. Forest Service which are needed for the French Broad Basin development would be transferred to TVA without cost, except for improvements.

During the construction period, the flow of the streams would be diverted either through tunnels located in the abutments or through conduits passing under the dams, depending upon the structural layout for the particular

unit. At Swannanoa, the only concrete structure, the dam would be built in stages with diversion through two 5- by 5-foot sluices located in the base of the left spillway bay. One of these sluices would be a permanent facility and the other one would be sealed after closure.

Provision would be made to handle a flood with a frequency of once in 6 years during the April-July period at the West Fork, Boylston, and Devils Fork units. In planning construction at the other units, since large quantities of fill would be involved in building the dams, the 6-year all-season flood was used in computing diversion capacities. Rockfill protection for the downstream slope of the earth embankments would be provided in case of overtopping during construction.

OPERATION

For best coordination and maximum efficiency, it is planned that the operation of all Howell-Bunger valves and the radial gates at the Swannanoa unit would be controlled remotely by TVA personnel from a control center located in the vicinity of the Asheville airport.

Metering and control would be exercised over a supervisory control cable or by radio from this central station. Information concerning valve opening positions and water levels at each impoundment, as well as elevations at selected locations along the stream channels, would be available continually at the control center. It is estimated that fourteen additional rain gages and six more stream gages would be needed to satisfactorily operate the system.

The estimated annual operation and maintenance cost for the dams and reservoirs, channel work, and levee is shown below:

Dams and reservoirs	\$ 70,400
Channels	31,600
Asheville levee	<u>6,000</u>
Total Annual Operation and Maintenance for System	\$108,000

The capital equivalent of this amount, used in comparison of benefits and costs, is equal to \$3,300,000.

ESTIMATED BENEFITS

The benefits derived from comprehensive development of the water resources of the French Broad River Basin in North Carolina would amount to \$143,000,000. They have been computed over the estimated 100-year life of the project, converted to a present-worth basis, and then capitalized at 3-1/8 percent.

Flood Control

The flood control benefits afforded by the plan of development have been classified in three categories, (1) agricultural, (2) urban, and (3) roads, railroads, and bridges. The total capitalized benefits amount to \$72,200,000.

Agriculture--More than one-half of the agricultural benefits for the system consist of reduced flood damage to growing crops. Damages also would be reduced to farm property such as land, fences, equipment, and livestock. With the reduced risk of flood loss, it would be possible to utilize some 13,000 acres of protected land to grow higher value crops. The increased value of production would be principally in fresh market produce. The estimated land-use changes are:

<u>Land Use</u>	<u>Without Project</u>		<u>With Project</u>	
	<u>Percent</u> <u>Land Use</u>	<u>Average</u> <u>Yield</u>	<u>Percent</u> <u>Land Use</u>	<u>Average</u> <u>Yield</u>
Corn	39.2	84 bu	35.1	97 bu
Pasture	23.3	165 cgd	19.1	180 cgd
Hay	8.5	2.1 ton	7.5	2.1 ton
Small grains	4.0	26 bu	3.0	26 bu
Soybeans	1.0	35 bu	1.2	35 bu
Bunch beans	5.8	160 bu	15.3	160 bu
Pole beans	2.8	260 bu	6.6	260 bu
Irish potatoes	.5	150 bu	4.5	150 bu
English peas	.8	1.5 ton	1.2	1.5 ton
Cucumbers	1.0	200 bu	1.7	200 bu
Other vegetables	.7	-	1.4	-
Gladioli	1.8	3500 doz	2.0	3500 doz
Idle land	7.6	-	3.4	-
Woodland	3.4	-	1.9	-
Nonfarm uses	<u>1.7</u>	-	<u>2.0</u>	-
Total	102.1		105.9	

The land use shown on the preceding table is greather than 100 percent because of double cropping. However, winter cover crops, commonly grown following vegetable crops but not harvested, are not listed.

In summary, the average annual benefits resulting from protection of agricultural land are as follows:

<u>Area</u>	<u>Net Flood Damage Reduction</u>			<u>Increased Income From More Intensive Land Use</u>	<u>Total</u>
	<u>To Crops</u>	<u>To Farm Property</u>	<u>To Land</u>		
Main stream	\$526,500	\$29,800	\$30,600	\$271,800	\$ 858,700
Tributaries	<u>75,600</u>	<u>10,900</u>	<u>7,500</u>	<u>166,300</u>	<u>260,300</u>
Total	\$602,100	\$40,700	\$38,100	\$438,100	\$1,119,000

When capitalized, these benefits amount to \$34,200,000

Urban--Urban benefits, or potential flood damages prevented, were estimated from field appraisals made of industrial, commercial, residential, and transportation facilities. They include estimates of direct physical damage to structures, stock, machinery, and equipment. The following table shows the flood damages prevented in the urban areas. No allowance has been made for disruption of community activities.

<u>Area</u>	<u>Avg Annual Value</u>	<u>Capitalized Value</u>
Rosman	\$ 16,300	\$ 498,000
Hendersonville	7,800	238,000
Fletcher	800	24,000
Enka	3,000	92,000
Asheville	819,000	25,009,000
Biltmore	311,000	9,493,000
Rollins	8,000	244,000
Marshall	34,300	1,047,000
Hot Springs	<u>1,800</u>	<u>55,000</u>
Total	\$1,202,000	\$36,700,000

Roads, Railroads, and Bridges--The flood storage provided by the reservoirs would give considerable protection to both U. S. and state highways, an 18-mile stretch of a branch line of the Southern Railway, and bridges along the streams. The annual benefit from protection of roads and bridges is estimated to be \$43,000, which would be \$1,300,000 when capitalized.

In summary, the estimated capital value of the flood control benefits to accrue from the system of dams and reservoirs, channel improvements, and levee is estimated to amount to \$72,200,000.

Water Supply

The value of the benefit to accrue from the storage of 19,200 acre-feet for water supply is based on the cost of the cheapest single-purpose alternative dam that would provide the same amount of storage as would be provided in the multiple-purpose reservoirs. This benefit is estimated to be \$131,000 annually, which, when capitalized, would amount to \$4,000,000. The increased flow provided for water quality control also would increase the water supply potential downstream from the impoundments. Such an inducement would make it more attractive for new industry to locate along the streams; however, no dollar value has been put on this benefit.

Water Quality Control

The benefits from water quality control are derived from augmentation of low flows (1) to provide dilution of residual wastes and increase the dissolved oxygen content in the water and (2) to dilute nitrogen and phosphorous nutrients that encourage growth of nuisance aquatic plants. The capitalized benefit of the water quality storage to be provided in the French Broad project is estimated to be \$32,000,000.

A separate document supports in detail the provision for water quality control.

Recreation

The annual visitor-day use for recreation after a 6-year development period for the eleven reservoir units incorporating this function is conservatively estimated to be about 300,000. At \$1 per recreation-day, the value placed upon day-use areas when certain minimum facilities are provided, as is customarily done in assessing recreational benefits in water control projects, the annual benefits amount to \$300,000. These benefits, discounted for the development period, would have a present worth of \$8,600,000.

The project cost includes \$600,000 as the estimated amount of capital investment necessary to provide initial recreation facilities for the entire project. Additional development by others would be necessary to capture the full recreational potential of the project.

Shoreline Development

Approximately 5300 acres of land adjacent to the reservoirs and above elevations reached by the maximum probable flood would be acquired in order to prevent unreasonable severance damage, avoid undue expense in providing access to isolated tracts, and ensure maximum development and use of the reservoirs for purposes of public benefit. The reservoirs would enhance the value of approximately 3600 acres of this land. This acreage, made up largely of remnants of tracts formerly in separate ownership which could be joined and provided with reasonable access, would be made available for those uses that would most effectively serve to stimulate economic development in the region. In addition, 4400 acres of adjoining land not required for the project would be enhanced by the project and related development.

These elements taken together would produce shoreline development benefits which are reflected in the project justification and which have an estimated value of \$13,500,000. Of this total, \$7,500,000 relates to the lands acquired for the project and \$6,000,000 represents increased values occurring on adjoining land.

Fish and Wildlife

During 1966 the North Carolina Wildlife Resources Commission designated about 200 miles of streams in the basin as public mountain trout waters and planned to stock these with rainbow, brook, and brown trout. Other streams, totaling many additional miles, support trout but are not stocked because of the small amount of fishing along them. The proposed reservoirs would eliminate about 11 miles, or an estimated 55 acres, of trout streams; but at the same time the reservoirs would improve the quality of the water downstream from the dams. Water discharged from the reservoirs would be colder than natural flows because the flow would be increased and would not warm up as readily as the smaller natural flow. It would also have from 4 to 9 ppm of dissolved oxygen which is considered desirable for trout. Further investigations now scheduled will assist in the design of the outlet works to ensure satisfactory conditions for a trout fishery.

The proposed lakes, with a total surface area of about 6700 acres and a total shoreline length of about 183 miles at normal pool levels, undoubtedly, would encourage heavy recreation use for stillwater fishing. It is estimated that the lakes would attract about 6 visits per acre per year the first year, and that the visitation would increase at the rate of 3 percent per year for the next 50 years and

thereafter at about 1.5 percent per year. Using \$1 per fishing visit and converting these totals to present worth, the capitalized equivalent would be \$3,200,000 for this benefit.

Wildlife of the adjacent hardwood forests--squirrel, grouse, and deer--is an important adjunct to the French Broad resource base, but it would be affected little or none by this project. No monetary wildlife value is assigned.

Area Redevelopment

The construction of the French Broad project in the 4-county area of North Carolina would help provide relief from unemployment and underemployment that exist in the area. The benefit that could be credited to the project would result from employment of local labor now unemployed or underemployed and the use of existing idle resources. The method used in determining this benefit is based upon U. S. Department of Commerce publication entitled "Determination of Area Redevelopment Benefits from Water Resources Projects," dated March 1964. The capital equivalent of this benefit is \$9,500,000.

LOCAL PARTICIPATION

TVA undertook these water control planning studies as part of TVA's assistance in preparation of a unified comprehensive resources development program for the 5-county region. In order that the proposed water control system may be fully developed and used to make its maximum contribution to accelerating economic growth in this area, local participation is essential.

The recently organized Upper French Broad Economic Development Commission has legal status but somewhat limited powers with respect to accepting responsibilities for or assisting in the development and use of a multiple-purpose water control system. The commission will seek expanded authority by special legislation in the 1967 session of the legislature.

One important phase of local participation is a vigorous program to be undertaken by the commission to obtain public understanding and acceptance of the new economic development tool which the water control system will provide. The commission will make plans for assuring optimum development and full use of the system in the interest of overall economic growth.

To further limit potential flood damages and to avoid creating new flood hazards the plan contemplates continued work with state and local organizations toward related land-use planning.

A separate statement will be issued outlining the program of local participation to be utilized.

ECONOMIC JUSTIFICATION

The total cost for economic appraisal, including an allowance of \$3,000,000 for interest during construction, is estimated to be \$99,000,000. The total capitalized net benefit is estimated to be \$139,700,000, which results in a benefit-cost ratio of 1.4 to 1.0.

In addition, there are some definite benefits for which no monetary value has been assigned, mainly industrial sites created, the value of increased water supply made available through provisions for water quality control, as well as intangible benefits difficult to appraise. The individual items are summarized as follows:

<u>Estimated Cost</u>	
Dams and reservoirs	\$ 81,400,000
Channel improvements	8,000,000
Asheville levee	<u>6,600,000</u>
Subtotal	96,000,000
Allowance for interest during construction	<u>3,000,000</u>
Total estimated cost for economics	\$ 99,000,000

<u>Estimated Capitalized Benefits</u>	
Flood control:	
Agricultural	\$ 34,200,000
Urban	36,700,000
Roads and bridges	1,300,000
Water supply	4,000,000
Water quality control	32,000,000
Recreation	8,600,000
Shoreline development	13,500,000
Fish and wildlife	3,200,000
Area redevelopment	<u>9,500,000</u>
Subtotal	143,000,000
Less capitalized allowance for operation and maintenance	<u>3,300,000</u>
Net capitalized benefit	\$139,700,000

Benefit-Cost Ratio

1.4:1.0

[illegible]

characteristics.
fishing, shoreline development
during highest known flood
flood flow at nearest gage,
minimum pool level.
at which gate operation begins (100-y
high by 40-foot-wide tainter gates.
that spillway would operate no more often
construction and occasional drawdown of
with transition to 8-foot-diameter circle.

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Table 1

SUMMARY OF PRINCIPAL FEATURES

DAMS AND RESERVOIRS

	West Fork	North Fork	East Fork	Little	Boylston	Mills	Mud	Devils Fork	Clear	Hooper	Cane	S Hominy	Swannanoa	Ivy	Total ^a
LOCATION															
Stream	West Fork	North Fork	East Fork	Little	Boylston	Mills	Mud	Devils	Clear	Hooper	Cane	S Hominy	Swannanoa	Ivy	
Mile	French Broad	French Broad	French Broad	River	Creek	River	Creek	Fork	Creek	Creek	Creek	Creek	River	Creek	
County ^b	Transylvania	Transylvania	Transylvania	Transylvania	Henderson	Henderson	Henderson	Henderson	Henderson	Henderson	Buncombe	Buncombe	Buncombe	Madison	
PURPOSES															
Flood control	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
Recreation	-	-	-	x	x	x	x	x	x	x	x	x	-	x	11
Water quality control	-	x	x	x	-	x	x	x	x	x	x	x	-	x	11
Water supply	-	-	-	-	-	x	x	x	-	-	-	-	-	x	5
STREAMFLOW															
Drainage area above dam site, square miles	18	37	25	60	14	66	11.1	4.6	42	10.8	40	30	95	129	583
Maximum probable flood at dam site:															
Natural, cfs	25,600	41,500	32,500	35,200	13,000	60,300	17,700	8,700	39,400	17,700	44,000	35,500	79,200	93,500	
Regulated, cfs	13,600	33,700	20,800	20,300	7,050	38,100	5,000	5,400	18,500	6,700	39,300	27,100	58,500	31,500	
Maximum known flood at dam site:															
Date	Oct 1964	Oct 1964	Oct 1964	Jul 1916	Dec 1950	Aug 30, 1940	Jul 1916	Jul 1916	Jul 1916	Jul 1916	Jul 1916	Aug 30, 1940	Jul 1916	Mar 1965	
Flow, cfs	4,400 ^c	9,200 ^c	9,100 ^c	36,100	805	13,400	10,400 ^c	6,700 ^c	19,700	10,300 ^c	18,500 ^d	8,450 ^c	21,100 ^c	13,000 ^d	
Average flow at dam site, cfs	61	125	85	191	31	157	20	8	76	13	47	34	113	122	
Minimum flow at dam site, cfs	6	14	14	24	5	18	2	1	8	2	6	5	1	7	
Date	Jan 1940	Jan 1940	Jan 1940	Oct 1954	Oct 1954	Dec 1943	Sept 1954	Sept 1954	Sept 1954	Sept 1956	Sept 1956	Sept 1953	Oct 1941	Jan 1940	
RESERVOIR															
Operating levels at dam:															
Maximum probable flood:															
Elevation	2649	2375	2341	2127	2135	2197	2170	2143	2138	2164	2216	2239	2162	2026	11,225
Area, acres	335	395	620	1340	630	1050	660	345	1780	375	700	465	1170	1360	
Spillway crest:															
Elevation	2635	2360	2330	2120	2127	2181	2162	2136	2128	2156	2205	2225	2120	2011	8,225
Area, acres	230	350	490	1200	470	840	520	255	1280	310	520	355	340	1065	
Total volume below crest, ac.-ft	5,500	25,400	16,300	23,600	9,300	27,500	10,300	3,100	24,200	6,000	11,500	10,800	7,400	55,000	
Normal maximum pool:															
Elevation	-	2335	2318	2108	2123	2168	2156	2134	2123	2151	2194	2209	-	2000	6,700
Area, acres	-	280	370	430	410	660	430	230	1030	270	390	245	-	885	
Volume, ac.-ft	-	17,400	11,000	11,000	7,500	17,500	7,500	2,600	18,300	4,600	6,700	6,000	-	43,600	
Length of shoreline, miles	-	9	18	11	11	14	8	4	29	5	10	8	-	41	183
Minimum pool:															
Elevation	-	2243	2262	2101	2120	2126	2140	2128 ^e	2118	2131	2172	2174	-	1971	3,875
Area, acres	-	75	55	680	365	140	230	145	510	110	130	65	-	530	
Volume, ac.-ft	-	1,400	1,000	5,600	6,400	1,500	2,300	1,400	13,700	700	1,000	1,000	-	23,600	
Controlled flood storage volume between spillway crest and normal maximum pool:															
Acres-feet	5,500	8,000	5,300	12,600	1,800	10,000	2,800	500	5,900	1,400	4,800	4,800	19,800 ^f	11,400	89,900
Inches on drainage area	5.7	4.1	4.0	3.9	2.4	2.8	4.7	2.0	2.6	2.4	2.3	3.0	3.9	1.7	
Allowance for sediment storage below spillway crest, ac.-ft	220	630	440	1,000	375	1,500	375	200	2,000	450	2,250	1,100	3,500	5,300	
Volume reserved for water quality control, ac.-ft	-	16,000	10,000	5,300	-	4,500	5,000	1,200	4,600	3,900	5,700	5,000	-	15,000	76,200
Volume reserved for water supply, ac.-ft	-	-	-	-	-	11,500	200	800 ^e	-	-	-	-	-	5,000	19,200
Reservoir clearing, elevation	2617	2336	2319	2109	2124	2169	2157	2135	2124	2152	2195	2210	2134	2001	
Families affected	6	4	25	60	10	80	15	20	80	20	90	35	70	100	595
DAM															
Material	earth	earth & rock	earth & rock	earth	earth	earth	earth	earth	earth	earth	earth	earth	concrete	earth & rock	
Total length along baseline, ft	490	730	585	960	850	2,400	1,100	760	1,060	1,490	975	840	853	780	
Maximum height above foundation, ft	92	190	144	58	66	110	65	43	75	69	73	117	132	214	
Top elevation	2656	2382	2347	2132	2139	2204	2175	2145	2142	2169	2220	2244	2169	2041	
SPILLWAY															
Type	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	broad weir	ogee ^g	broad weir	
Material	concrete	concrete	concrete	concrete	concrete	concrete	concrete	riprap	concrete	concrete	concrete	concrete	concrete	conc & rock	
Crest elevation ^h	2635	2360	2330	2120	2127	2181	2162	2136	2128	2156	2205	2225	2120	2011	
Crest length	100	200	200	400	100	200	100	100	200	100	400	200	80	200	
Discharge at maximum probable flood, cfs	13,400	33,200	20,500	19,400	6,750	36,800	4,800	5,300	17,350	6,500	38,700	26,700	57,100	29,700	
Velocity at maximum probable flood, fps	16	16	14	11	12	17	12	11	13	12	14	16	30	17	
Head at maximum probable flood, ft	14	15	11	7	8	16	8	7	10	8	11	14	42	15	
RESERVOIR CONTROL WORKS															
Regulating works, type	sluiceway	36" H-B valve	30" H-B valve	60" H-B valve	spillway notch 4' x 14'	66" H-B valve	30" H-B valve	24" H-B valve	60" H-B valve	30" H-B valve	48" H-B valve	36" H-B valve	sluiceway	66" H-B valve	
Water conductor:															
Type	R C conduit	tunnel	tunnel	tunnel	R C conduit ^j	tunnel	R C conduit	R C conduit	R C conduit	R C conduit	R C conduit	tunnel	opening in dam	tunnel	
Size	36" D	7' D	7' D	7' D	42" D	7' D	60" D	48" D	96" D	54" D	84" D	7' D	5' x 5'	7' D	
Length, ft	530	845	490	665	350	490	385	240	420	345	785	90	90	785	
Invert elevation, downstream	2560	2195	2188	2071	2075	2095	2107	2100	2072	2109	2148	2124	2043	1824	
Discharge at 100-year flood, cfs	220	550	330	820	285	1250	220	120	1040	200	580	420	1360	1780	
Maximum probable tailwater, elevation	2576	2215	2223	2095	2087	2120	2119	2111	2089	2121	2168	2156	2088	1832	
ESTIMATED MAJOR CONSTRUCTION QUANTITIES															
Dam:															
Impervious rolled fill, cu yd	224,000	527,000	234,000	202,000	228,000	958,000	371,000	129,000	421,000	527,000	475,000	614,000	-	687,000	5,596,000
Rock, cu yd	7,000	442,000	193,000	11,000	9,000	43,000	18,000	13,000	18,000	31,000	24,000	17,000	68,000	594,000	1,418,000
Concrete, cu yd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68,000
Spillway:															
Earth excavation, cu yd	76,000	182,000	221,000	123,000	40,000	180,000	154,000	90,000	31,000	155,000	168,000	197,000	-	37,000	1,612,000
Rock excavation, cu yd	6,000	-	-	-	-	-	-	-	-	-	10,000	-	3,000	70,000	89,000
Concrete, cu yd	1,500	2,000	1,900	3,250	1,200	2,050	1,050	-	1,870	1,000	3,400	4,850	25,200	300	49,570

a. Totals include ultimate Swannanoa characteristics.

b. Other benefits are redevelopment, fishing, shoreline development, and economic impact.

c. Estimated, using rainfall recorded during highest known flood in vicinity.

d. Estimated from maximum recorded flow at nearest gage.

e. Water supply provided within minimum pool level.

f. Flood storage below level at which gate operation begins (100-year flood frequency elevation 2142 for initial project and elevation 2152 after five years).

g. Equipped with two 36-foot-high by 40-foot-wide tainter gates.

h. Crest elevation set so that spillway would operate no more often than once in 100 years on the average, Swannanoa crest gated, see note f.

i. For diversion during construction and occasional drawdown of pool.

k. At upstream end; with transition to 6-foot-diameter circle.

Table 2
SUMMARY OF PRINCIPAL FEATURES
CHANNEL IMPROVEMENTS

	Buncombe County	Henderson County					Transylvania County			
	Swannanoa River	French Broad River	Mud Creek	Devils Fork	Bat Fork	Cane Creek	French Broad River	Nicholson Creek	King Creek	Total
Location										
Excavation - Mile to mile	0.7-2.1	165.2-184.0	0-5.4	0-1.2	0-2.5	0-2.4	184.0-207.8	0-1.6	0-1.0	
Clearing only - Mile to mile	0-0.7 2.1-5.0	-	5.4-7.0	-	-	2.4-4.7	207.8-216.0	-	-	
Streamflow										
Measured at mile	0	166.0	0.4	0.6	0.2	0.6	187.2	0.5	0.8	
Drainage area - Total, square miles	133	635	112	9	25	87	230	5	4	
- Controlled, square miles	95	369	58	5	0	51	120	0	0	
5-Year crop season flow - Natural, cfs	5,600	15,800	5,100	700	1,375	2,850	9,700	600	550	
- Regulated, cfs	2,000	10,000	2,650	600	1,280	1,550	5,900	600	550	
Channel										
Approximate width:										
Present conditions, feet	40-90	70-150	35-55	12-20	15-25	30	50-70	10	12	
After improvements, feet	(a)	110-218	52-60	16-28	31-57	30-34	75-110	10-15	12-14	
Maximum depth of excavation, feet	4	9	2	3	3	4	6	3	3	
Approximate bankfull capacity:										
Measured at mile	0	166.0	0.4	0.6	0.2	0.6	187.2	0.5	0.8	
Present conditions, cfs	5,500	6,500	1,400	400	700	1,100	2,340	430	450	
After improvements, cfs	5,550	10,000	2,650	600	1,280	1,550	5,900	600	550	
Length of improvement:										
Excavation, miles	1.4	18.8	5.4	1.2	2.5	2.4	23.8	1.6	1.0	58.1
Clearing, miles	3.6	-	1.6	-	-	2.3	8.2	-	-	15.7
Flood Protection to Agricultural Land										
Area flooded:										
Present conditions, acres	(b)	3,900	2,050	270	140	750	5,800	120	60	14,150 ^c
Area protected:										
After improvements, acres ^d	(b)	3,500	1,200	30	25	600	5,200	110	40	11,575 ^c
Land Easements Required										
Width, feet	90	300	120	50	120	50	300	50	50	
Area, acres	15	670	80	10	30	40	830	10	10	1,695
Construction Quantities										
Excavation:										
Unclassified, cubic yards	44,600	4,025,000	258,000	24,000	137,000	29,300	2,275,000	10,400	9,200	) 6,874,500
Rock, cubic yards	-	39,000	-	-	-	-	21,000	2,000	-	

a. Deepening only
b. Urban and industrial flood protection
c. Excluding agricultural lands protected by dams only
d. Minimum - 5-year crop season flood

Table 3

SUMMARY OF COST ESTIMATES

	<u>Dams and Reservoirs</u>	<u>Channel Improvements</u>	<u>Levee</u>	<u>Total</u>
Land and acquisition	\$19,345,000	\$ 514,000	\$ 176,000	\$20,035,000
Relocations	10,572,000	491,000	71,000	11,134,000
General yard	1,280,000	-	-	1,280,000
Clearing	1,368,000	496,000	-	1,864,000
Dam and spillway	16,932,000	-	-	16,932,000
Sluiceway	4,243,000	-	-	4,243,000
Access roads	462,000	-	-	462,000
Reservoir facilities	594,000	-	-	594,000
Levee	-	-	2,831,000	2,831,000
Storm drainage	-	-	1,272,000	1,272,000
Channel work	-	<u>3,817,000</u>	-	<u>3,817,000</u>
Total Direct Cost	54,796,000	5,318,000	4,350,000	64,464,000
General construction costs	15,373,000	1,525,000	1,250,000	18,148,000
Contingency	<u>11,231,000</u>	<u>1,157,000</u>	<u>1,000,000</u>	<u>13,388,000</u>
Total	\$81,400,000	\$8,000,000	\$6,600,000	\$96,000,000

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4 begins 9-2-95

23.1'

16 to Dec. 31, 1916

MAY

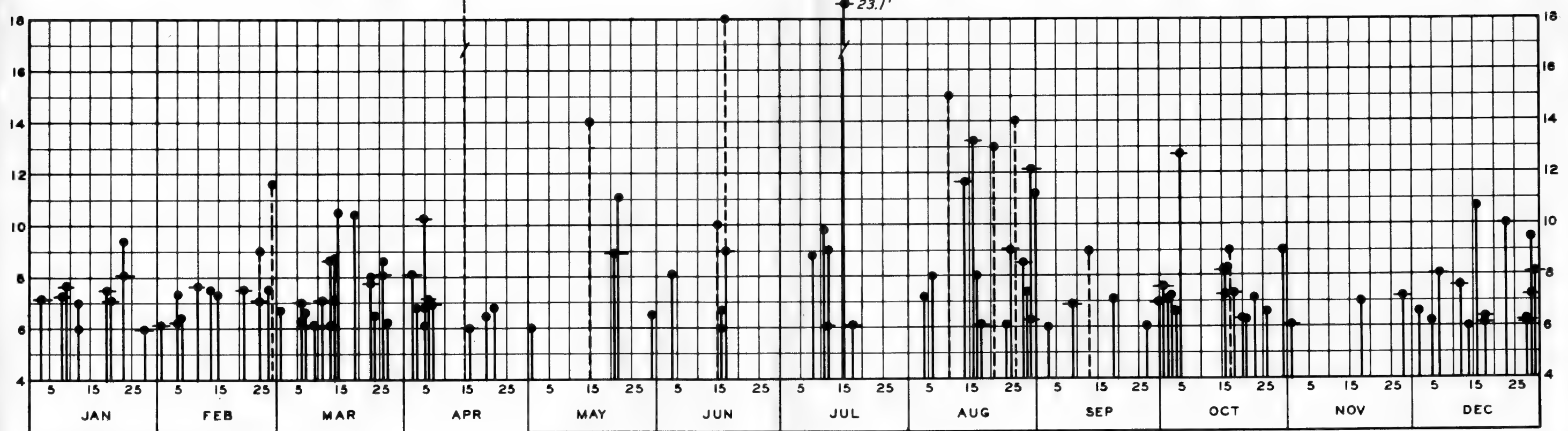
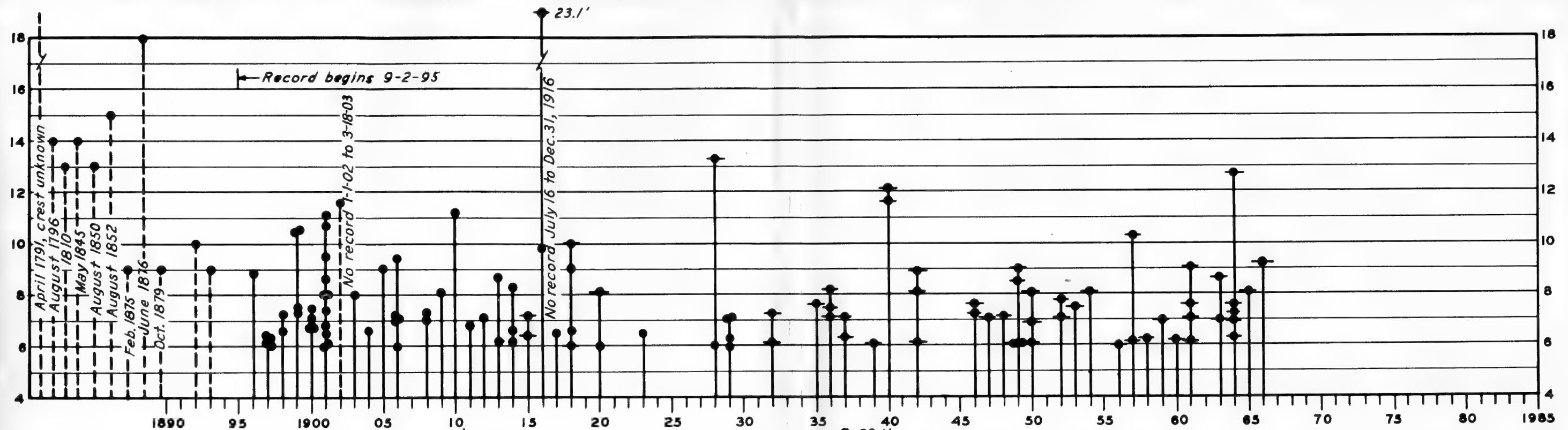
JUN

NOTE:

All stages are crests, some being estimated from the remainder being estimated from the methods. Stages for Oct. 1, 1922 (Pearson Bridge) and datum, when July 24, 1930; for Sept. 2, 1895 to site but corrected for a difference Sept. 30, 1922 are equivalents on Bridge, 1.58 miles upstream. Pre known, are shown on the lower diagram in the order of the July 16, 1916



STAGE ON USGS GAGE AT PEARSON BRIDGE



Gage Zero=1950.28 (1936 Suppl. adj.)

Drainage Area=945 sq. mi.

Approx. Flood Stage: Flooding begins at 5 feet
Appreciable damage at 9 feet

NOTE:

All stages are crests, some being reported and designated thus $\bullet$, and the remainder being estimated from daily or oftener gage readings and other methods. Stages for Oct. 1, 1922 to date are for gages at the present site (Pearson Bridge) and datum, where a recorder has been used since July 24, 1930; for Sept. 2, 1895 to Dec. 31, 1901 are from a gage at the present site but corrected for a difference in datum; and for Mar. 19, 1903 to Sept. 30, 1922 are equivalents on the present gage from gages at Smith Bridge, 1.58 miles upstream. Pre-record floods, for which the month is known, are shown on the lower diagram. The 1791 crest is reported to have been in the order of the July 16, 1916 flood.

Complete to June 30, 1966

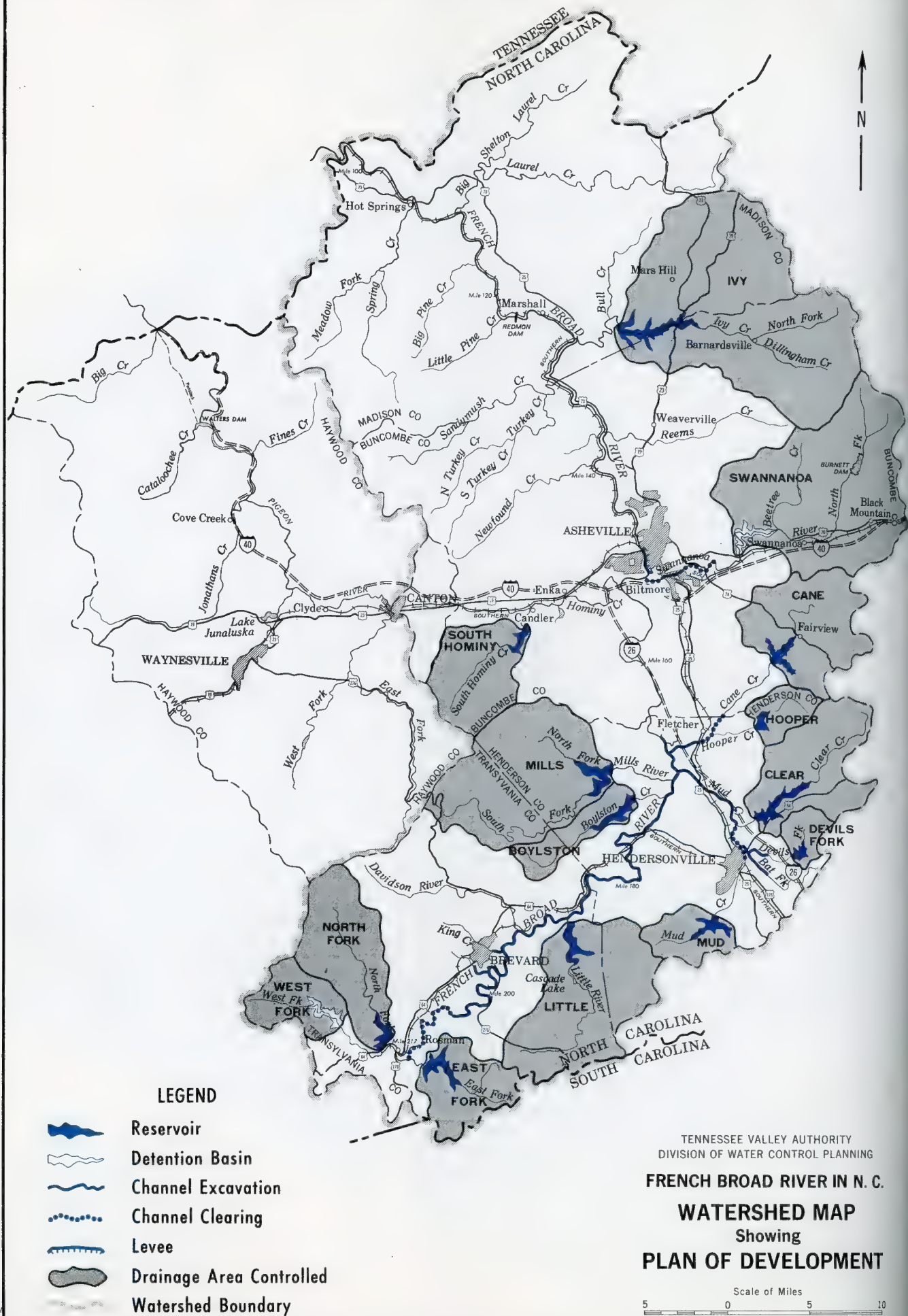
THIS DRAWING
SUPERSEDES:
W FC 1 311B160

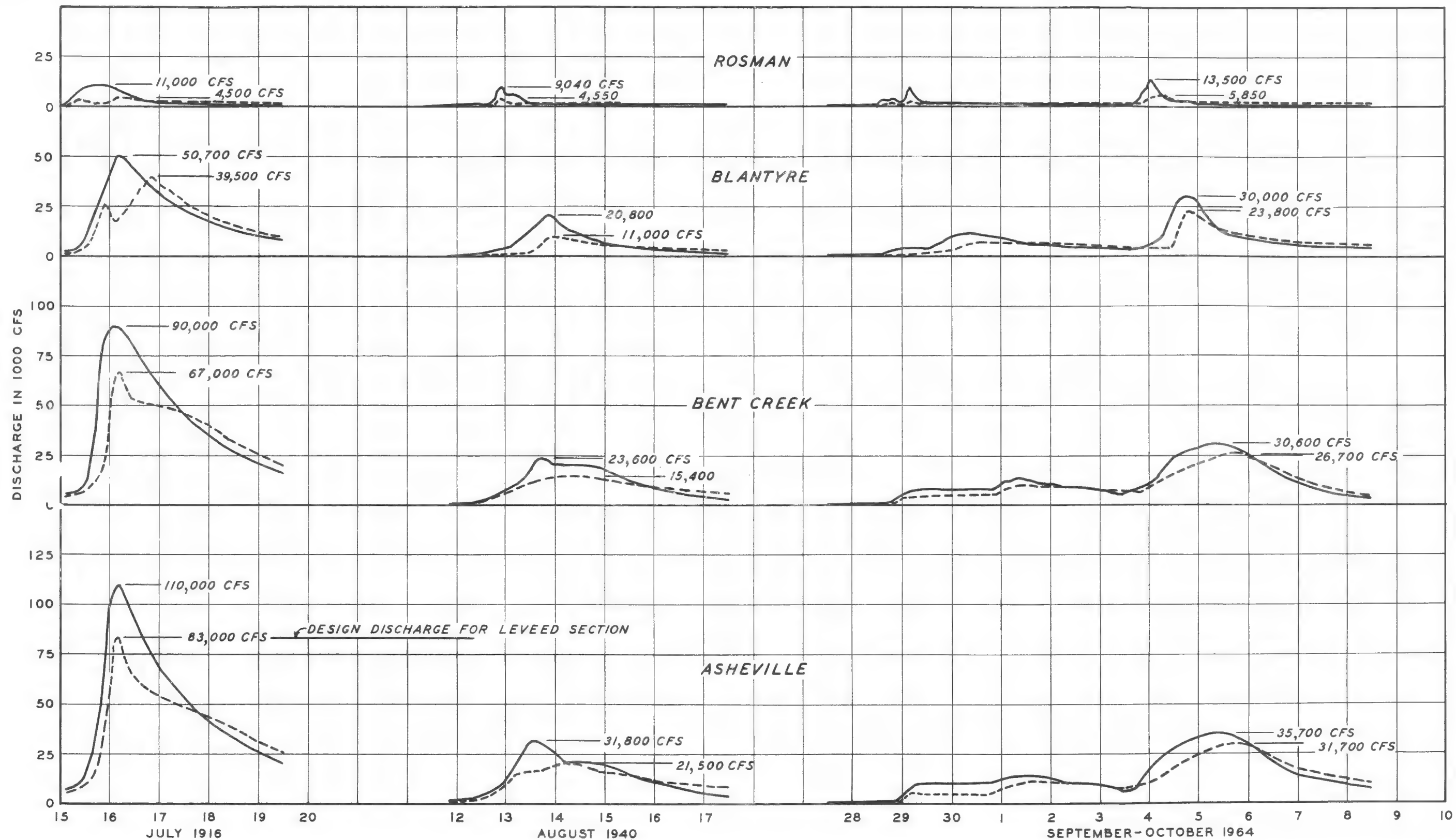
FRENCH BROAD RIVER MILE 145.75

DISTRIBUTION OF FLOODS
AT ASHEVILLE, N.C.

FLOOD CONTROL BRANCH
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED <i>W. H. H. H.</i>	RECOMMENDED <i>Art. B. H. H.</i>	APPROVED <i>R. A. H. H.</i>
KNOXVILLE	11-16-65	W FC 1 311B364 RI





SYMBOLS:

———— NATURAL
 - - - - - REGULATED

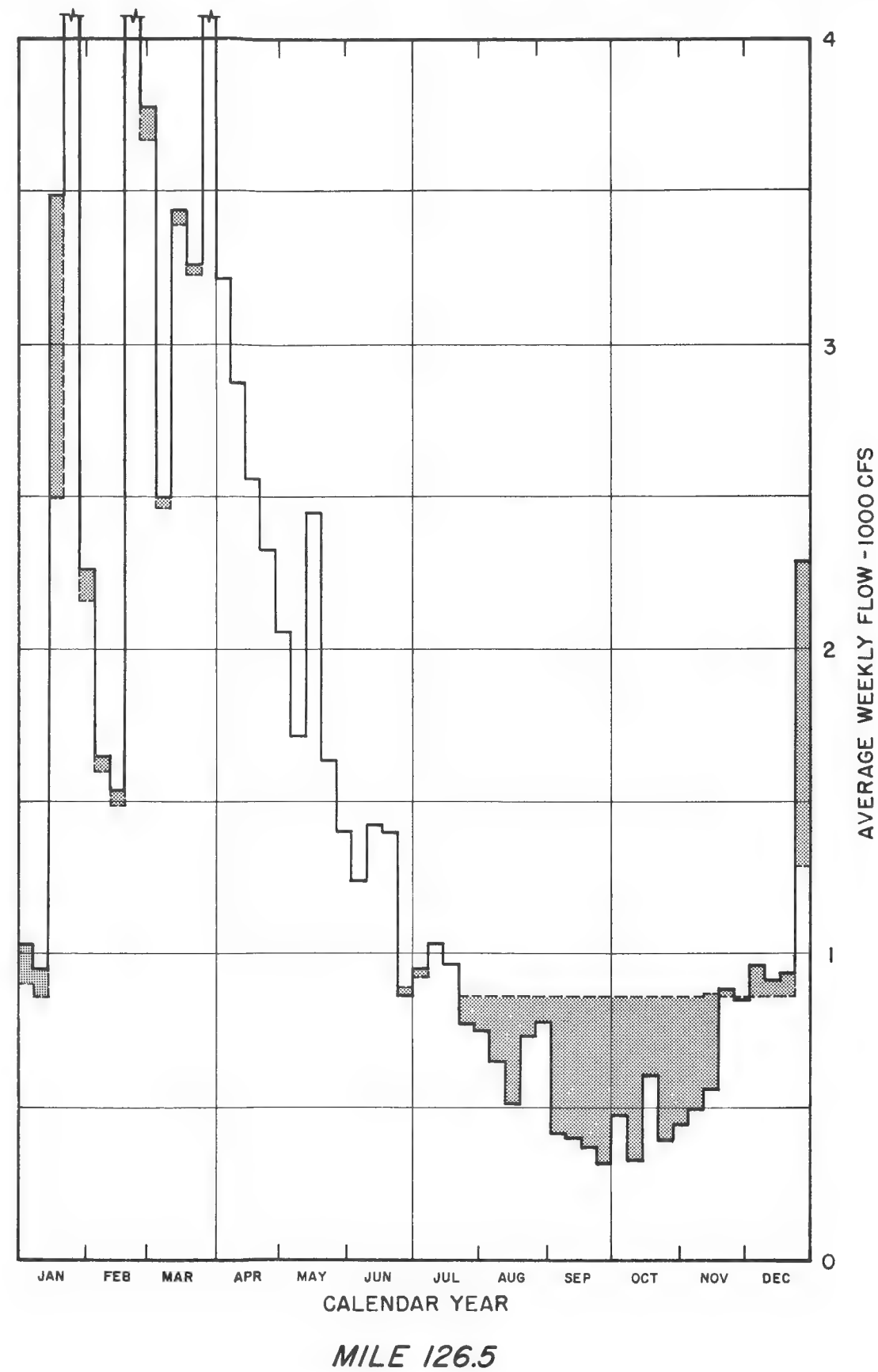
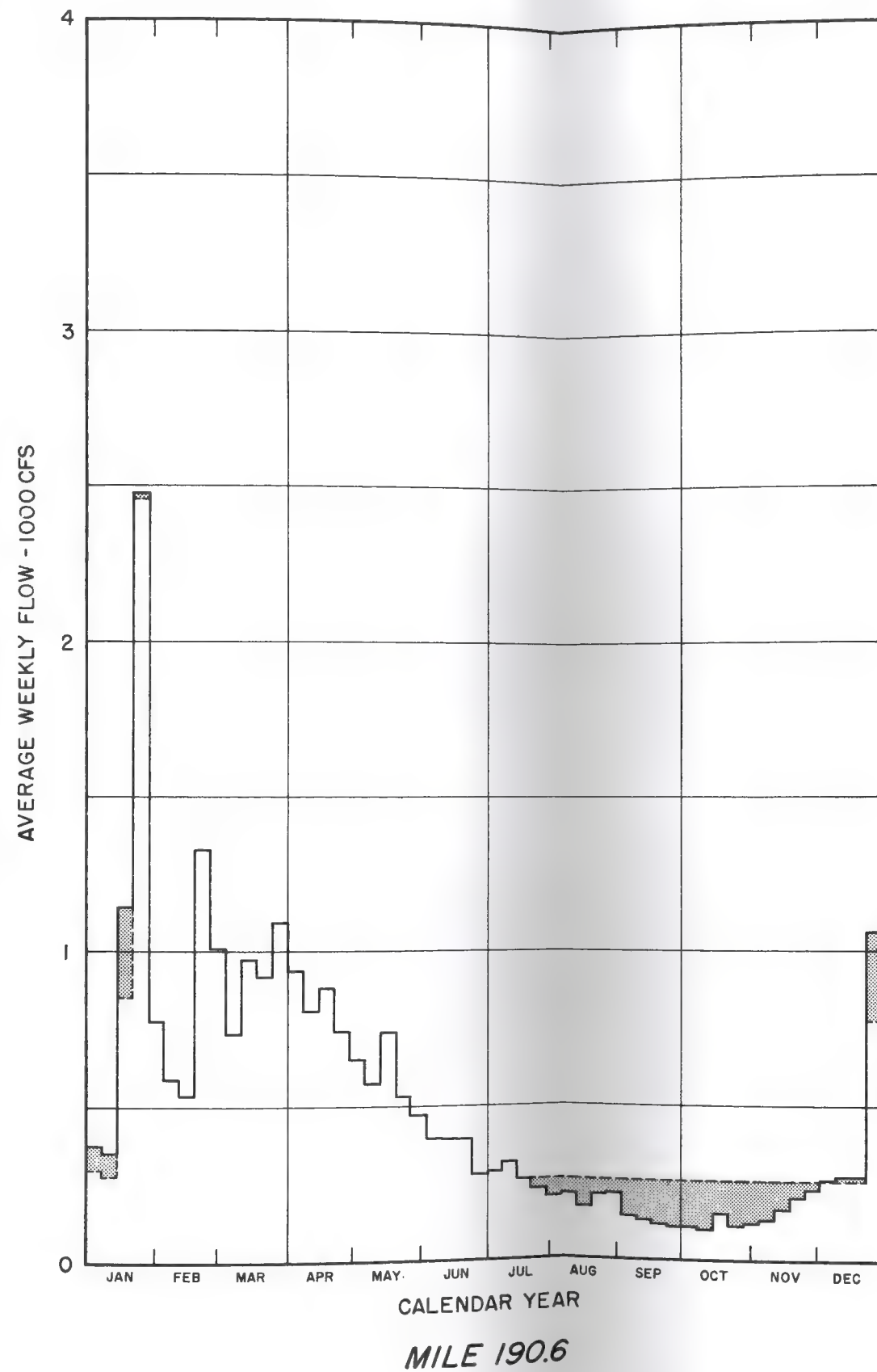
FRENCH BROAD RIVER

NATURAL AND REGULATED FLOOD HYDROGRAPHS

FRENCH BROAD RIVER IN N.C.
 TENNESSEE VALLEY AUTHORITY
 DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
D.W. Stanton	Bob Buckler	R.A. Lee
KNOXVILLE	4-1-66	77 FC 1 312B 57

REV. NO.	DATE	MADE	CHD	SUPV	INSP
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LEGEND:

- Natural flow
 - - - Flow as regulated by operation of proposed reservoirs

FRENCH BROAD RIVER - MILES 190.6 & 126.5

REGULATION FOR LOW FLOW AUGMENTATION DRY YEAR - 1954

FRENCH BROAD RIVER IN N.C.
 TENNESSEE VALLEY AUTHORITY
 DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
J. P. Hinton	Don H. Matton	R. L. Elliott
KNOXVILLE	3-16-66	77 PP 1

321B2030R1

1	2-17-66	EH	BJW
General revision			
REV NO.	DATE	MADE	CHKD SUPV INSP
DRWN	EH	COMPUTED	WRP, BJW, EH
TRCD		ENGINEER	
CHKD	WRP		

LEGEND

- | | | | |
|---|---|---|--|
|  | Lower, Middle, and Upper Cambrian, and Lower Ordovician carbonate rocks |  | Metasedimentary rocks (Brevard schist) |
|  | Basal Cambrian rocks |  | Gneisses and Schists of the Inner Piedmont |
|  | Precambrian Clastic rocks |  | Massive to weakly foliated granitic rocks |
|  | Gneisses and Schists of the Blue Ridge |  | Foliated granitic rocks |
|  | Max Patch granite and Cranberry granite |  | Ultramafic rocks |

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED <i>R. J. Johnson</i>	RECOMMENDED	APPROVED <i>Barton S. Montgomery</i>
KNOXVILLE	4-13-66	77 GE 1 820 G 135

ITEM	FIRST YEAR			SECOND YEAR			THIRD YEAR			FOURTH YEAR			FIFTH YEAR			SIXTH YEAR			SEVENTH YEAR			EIGHTH YEAR																																						
	J	F	M	J	J	A	S	O	N	D	J	F	M	J	J	A	S	O	N	D	J	F	M	J	J	A	S	O	N	D	J	F	M	J	J	A	S	O	N	D																				
LAND ACQUISITION																																																												
NORTH FORK DAM																																																												
EAST FORK DAM																																																												
WEST FORK DAM																																																												
SOUTH HOMINY CREEK DAM																																																												
SWANNANOA RIVER DAM																																																												
DEVILS FORK DAM																																																												
MUD CREEK DAM																																																												
CLEAR CREEK DAM																																																												
IVY CREEK DAM																																																												
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HOOPER CREEK DAM																																																												
MILLS RIVER DAM																																																												
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MAINTENANCE CENTERS & STORAGE BUILDING																																																												
INTERSITE COMMUNICATION CENTER																																																												
FRENCH BROAD RIVER CHANNEL IMPROVEMENT																																																												
KING CREEK CHANNEL IMPROVEMENT																																																												
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CANE CREEK CHANNEL IMPROVEMENT																																																												
ASHEVILLE LEVEE																																																												
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FISCAL YEAR	FIRST							SECOND																																																				
EXPENDITURE REQUIREMENT DURING FY-THOUSAND \$	7,000							16,000																																																				

NOTES:

1. LAND ACQUISITION WILL BEGIN UPON AUTHORIZATION OF PROJECT.
2. EXPENDITURE REQUIREMENT SHOWN EXCLUDES \$1,500,000 PRIOR YEARS EXPENDITURES.

GENERAL

SUMMARY OF CONSTRUCTION
PLANNING SCHEDULESFRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF CONSTRUCTION

SUBMIT	RECOMMENDED	APPROVED
<i>J. C. Shum</i>		

KNOXVILLE 4-21-88 77 CP 3 102 B I

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BLACK DAM SITE, LOOKING UPSTREAM

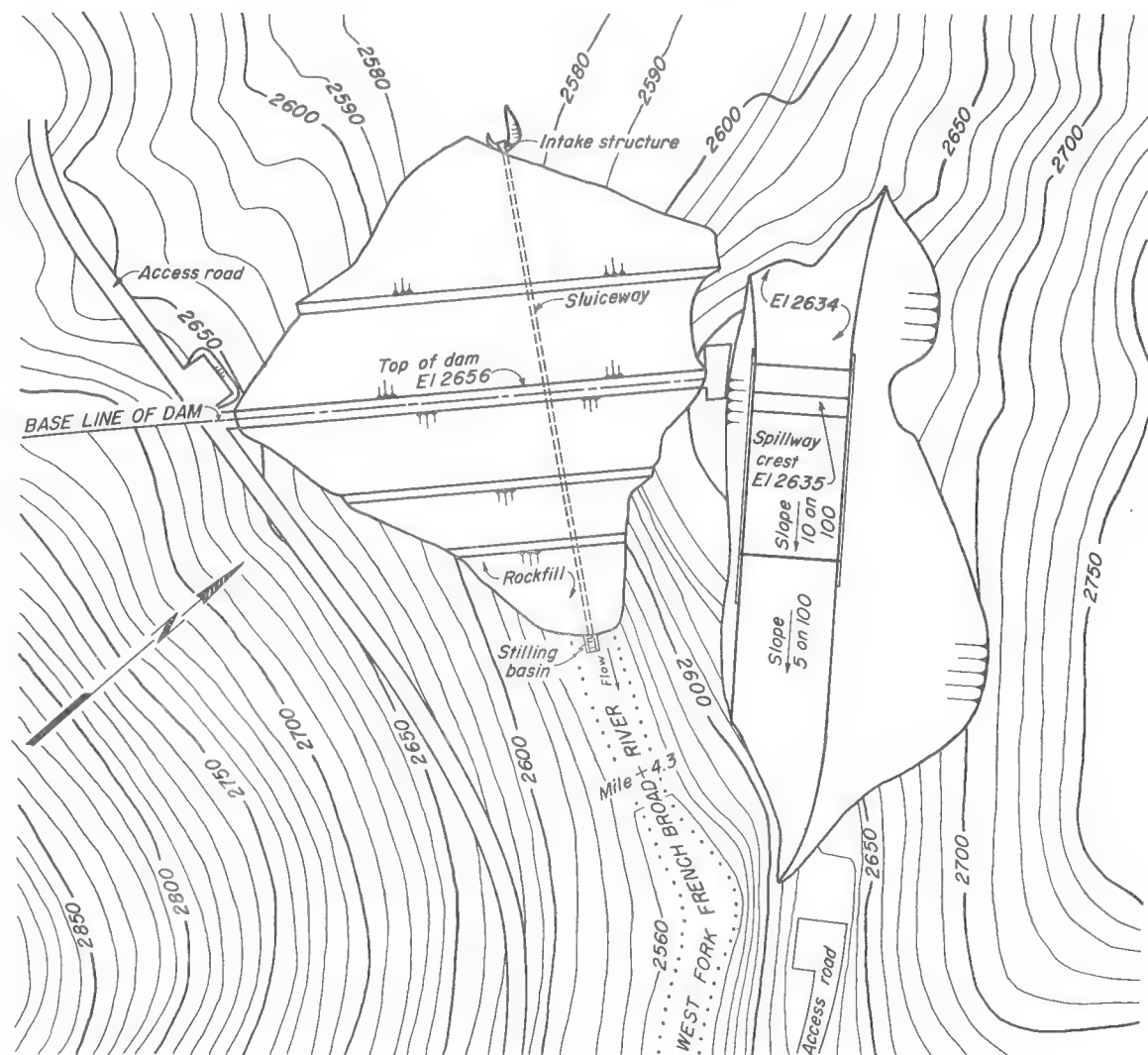
YEAR	FOURTH YEAR												FIFTH YEAR												SIXTH YEAR												SEVENTH YEAR														
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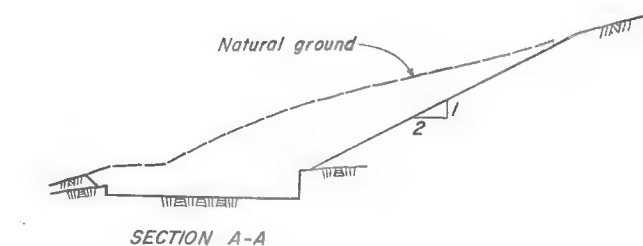
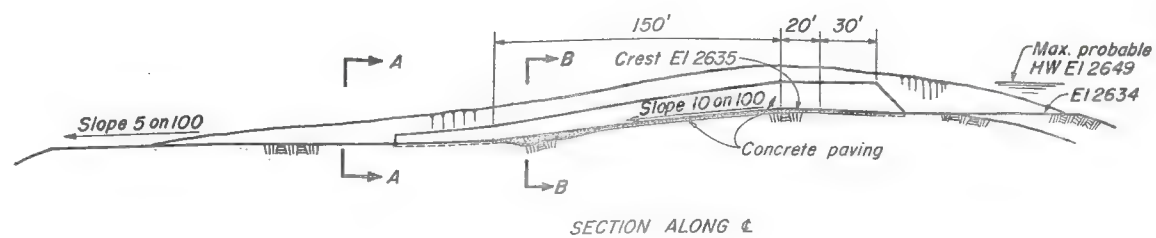


Figure 13 - WEST FORK DAM SITE, LOOKING UPSTREAM

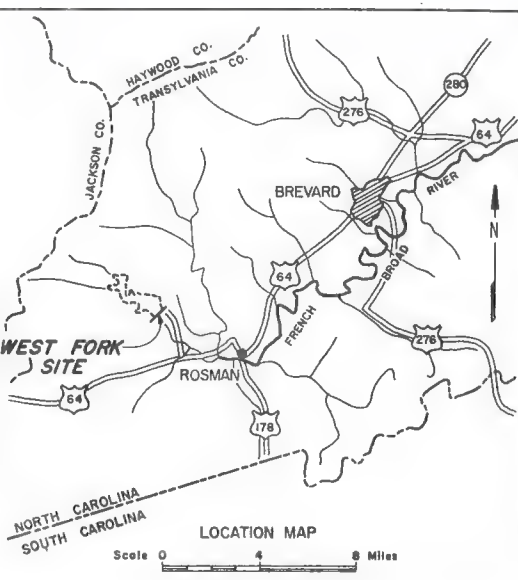
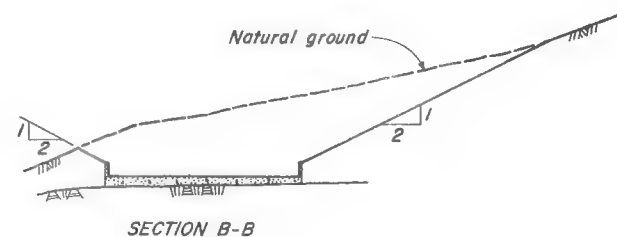
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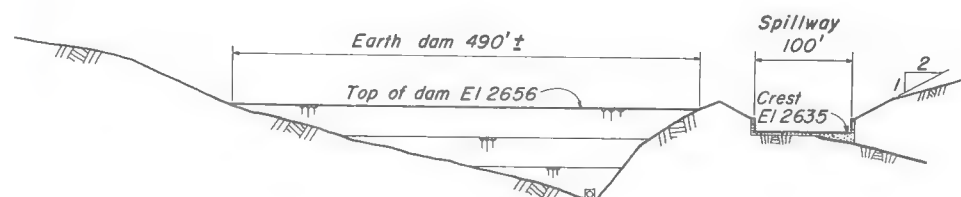
GENERAL PLAN



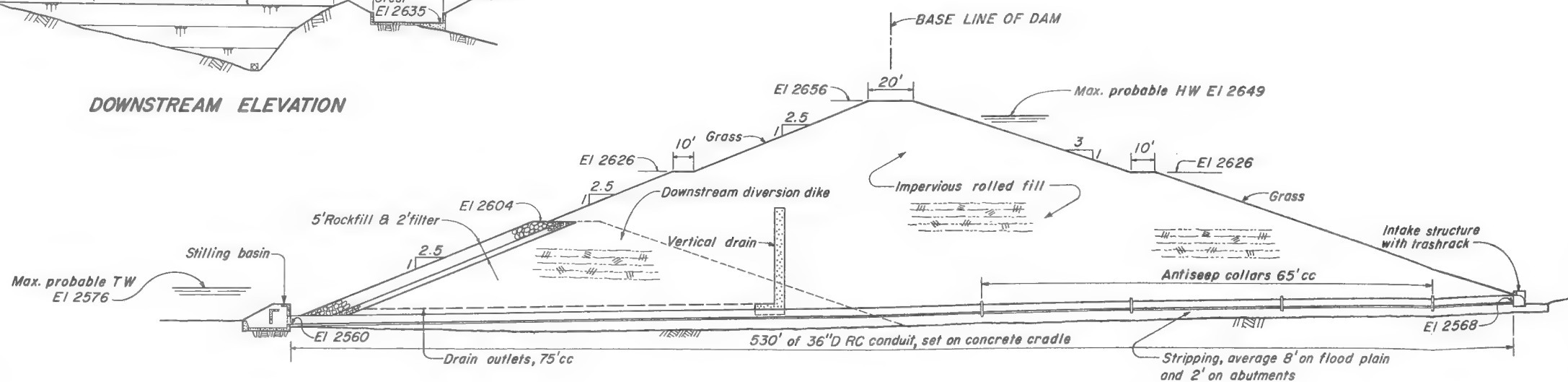
SPILLWAY



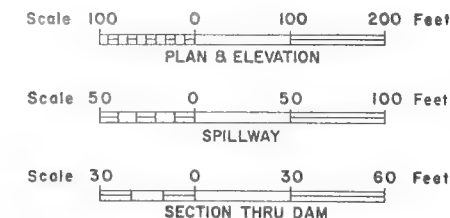
NOTE:
1. Topography taken from Kelsh topography, 461 Q 734-401 RI.
2. Detention structure only.



DOWNSTREAM ELEVATION



SECTION THRU DAM ALONG & OF SLUICeway



WEST FORK-MILE 4.4

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
<i>Jack H. Woodruff</i>	<i>Don H. Matney</i>	<i>R. L. Edwards</i>
KNOXVILLE	3-17-66 77V/PP	120 K 269R

1	8-18-66	MTW	JWF			
REV	NO.	DATE	MADE	CHKD	SUPV	INSP
DRWN	MTW	COMPUTED	TSG, DBC			
TRCD		ENGINEER				
CHKD	EH					



Scale 1000 0 1000 2000 Feet

WEST FORK-MILE 4.4

DETENTION BASIN MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

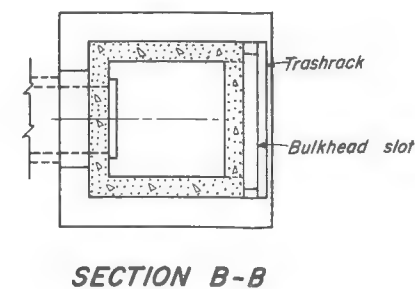
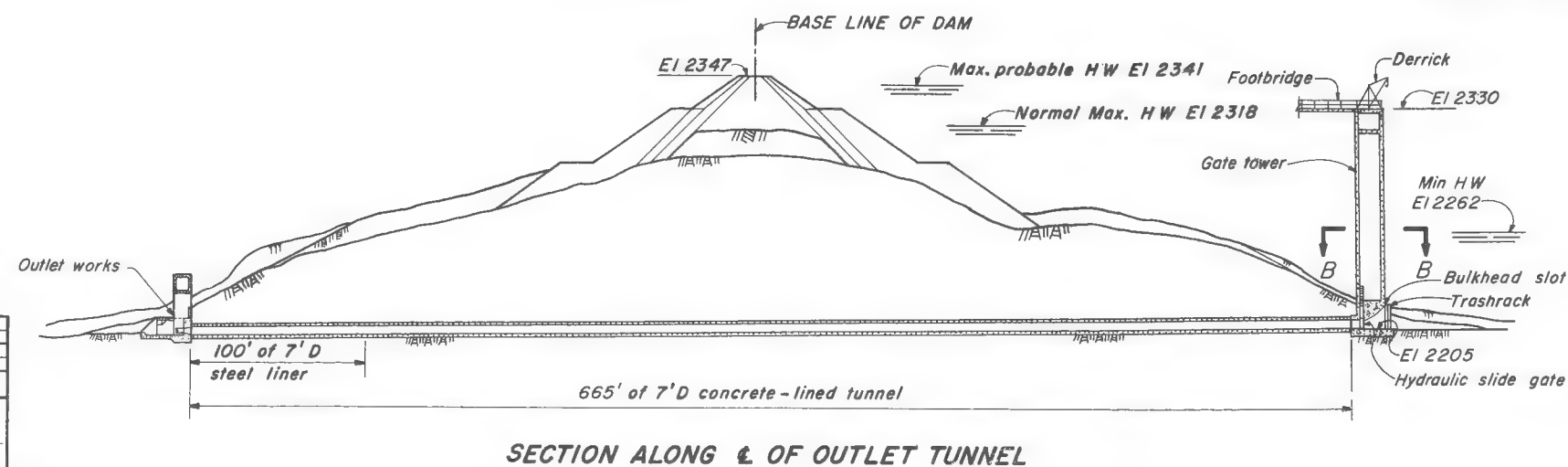
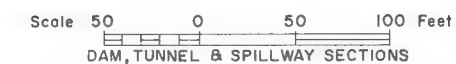
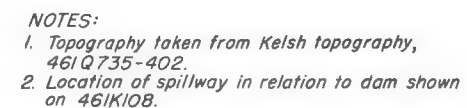
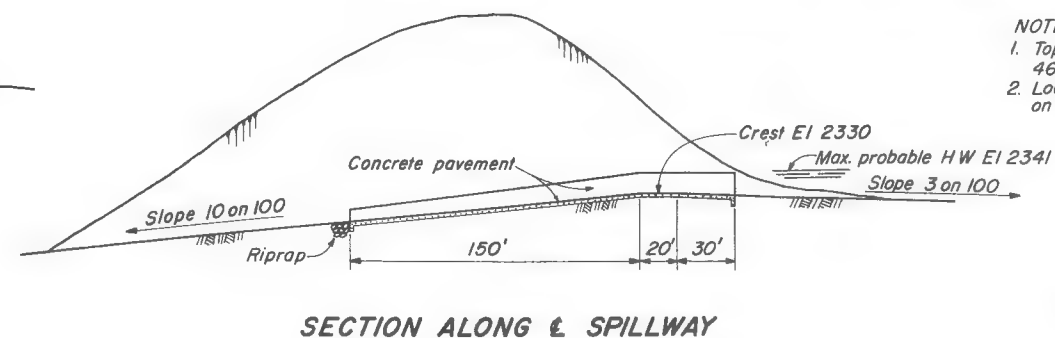
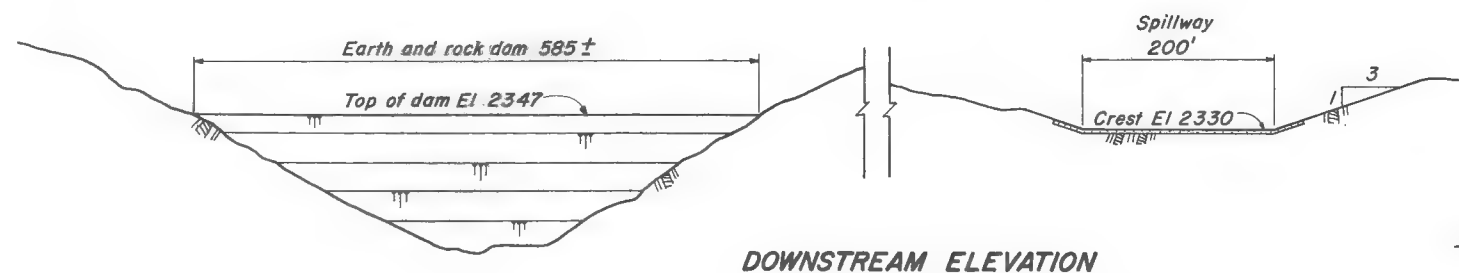
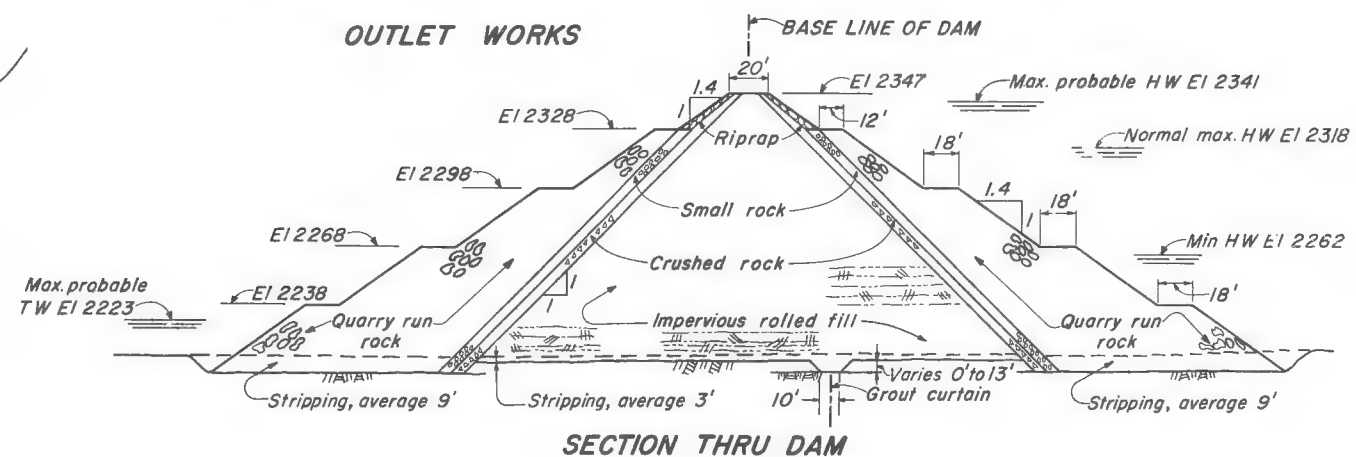
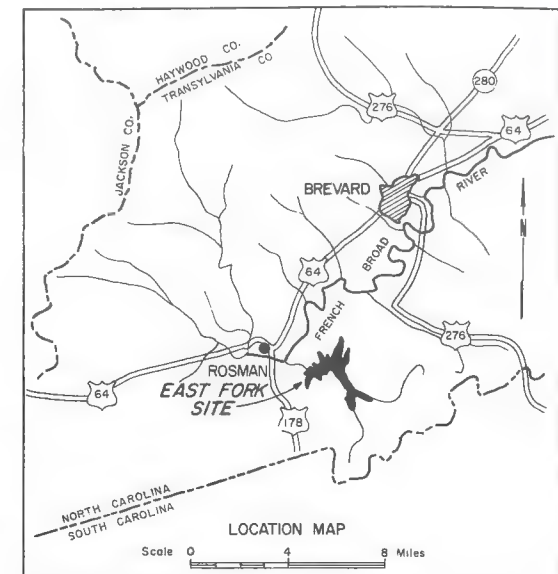
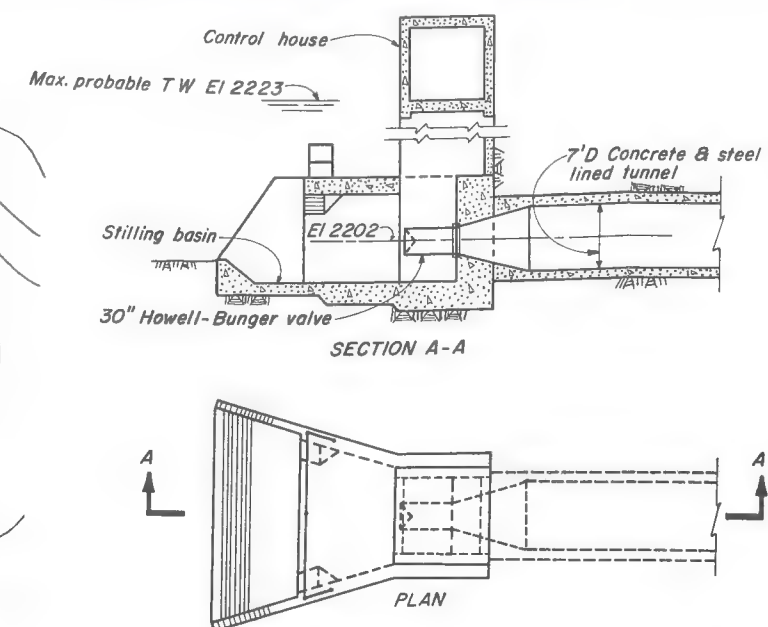
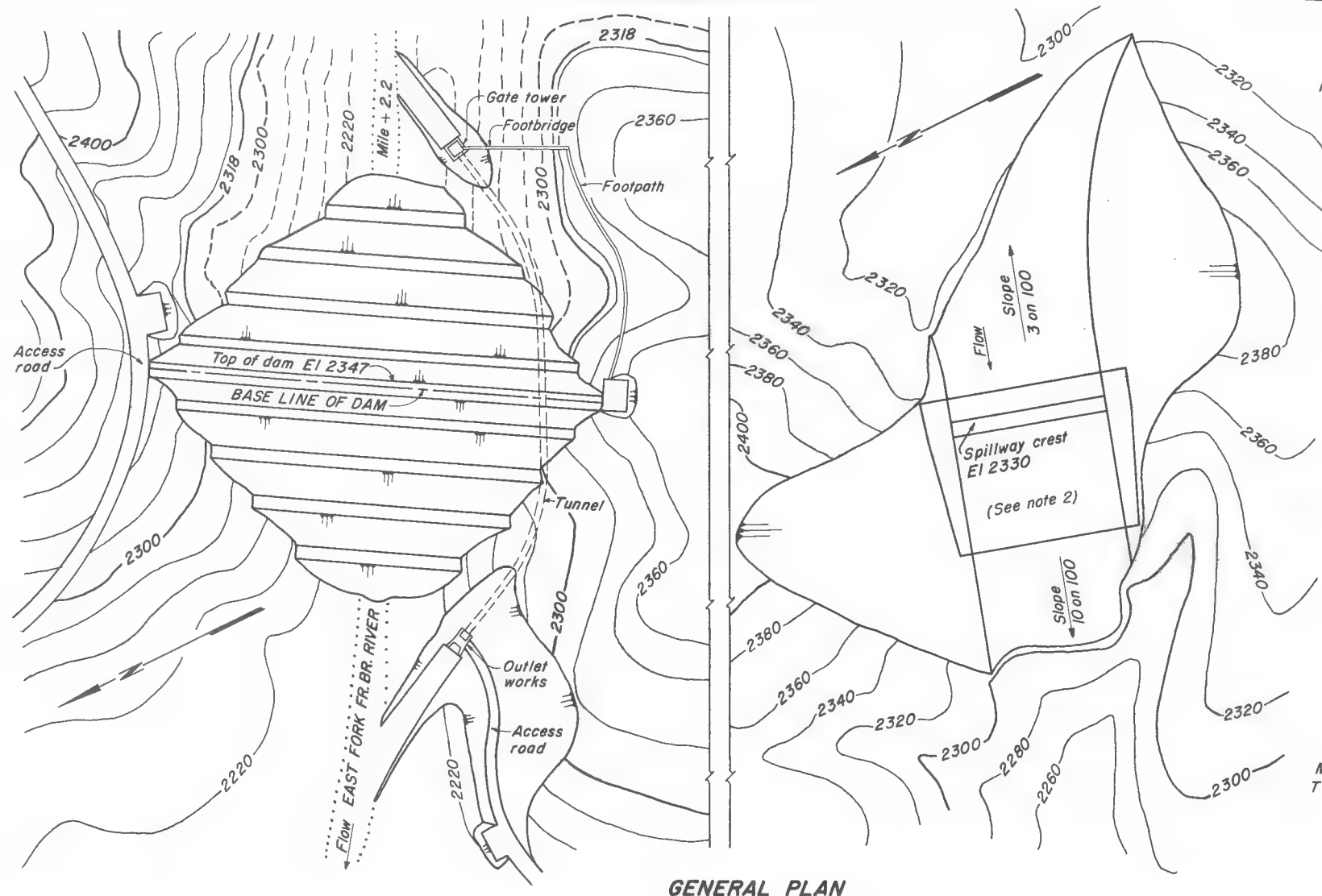
SUBMITTED <i>J. H. Blair</i>	RECOMMENDED <i>Don H. Matton</i>	APPROVED <i>R. E. Smith</i>
KNOXVILLE	2-1-66	77V PP 1 453B298

REV NO.	DATE	MADE	CHNG	SUPV	INSP
DRWN _____			COMPUTED _____		
TRCD _____			ENGINEER _____		
CHNG _____			<i>J. W. Brinkley</i>		



Figure 14 - EAST FORK DAM SITE, LOOKING DOWNSTREAM

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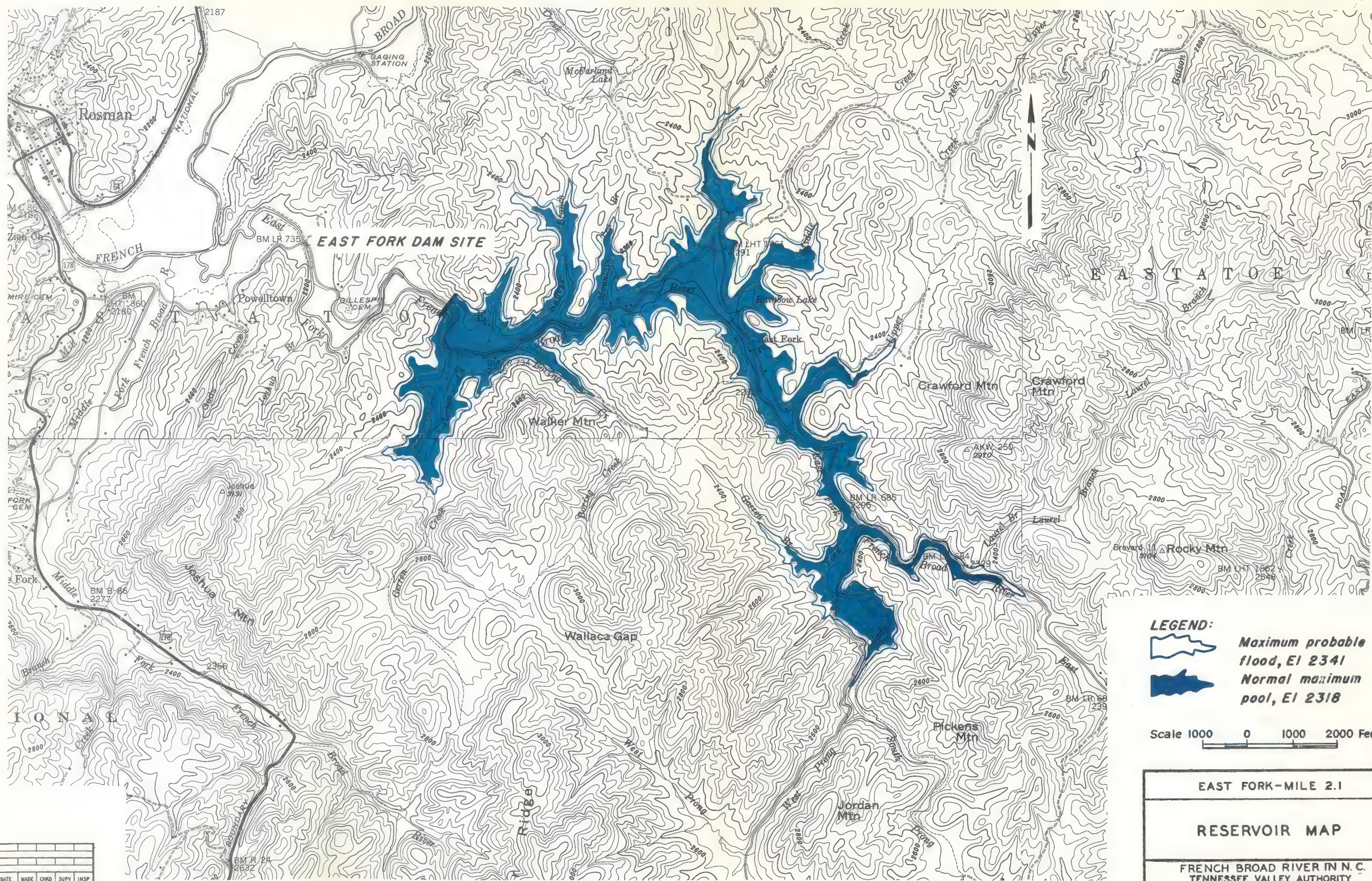
EAST FORK-MILE 2.1

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N. C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
<i>Jack H. Henshaw</i>	<i>Don H. Matten</i>	<i>W. Ellis</i>
KNOXVILLE	3-17-66	77U PP 1 120 K 270R

1		8-19-66		MTW		JWF	
General revision							
REV NO.	DATE	MADE	CHKD	SUPV	INSP		
DRWN MTW				COMPUTED			
TRCD				TSF, JWF			
CHKD JWB				ENGINEER			
				<i>J W Bumbley</i>			



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Figure 15 - NORTH FORK DAM SITE, LOOKING UPSTREAM

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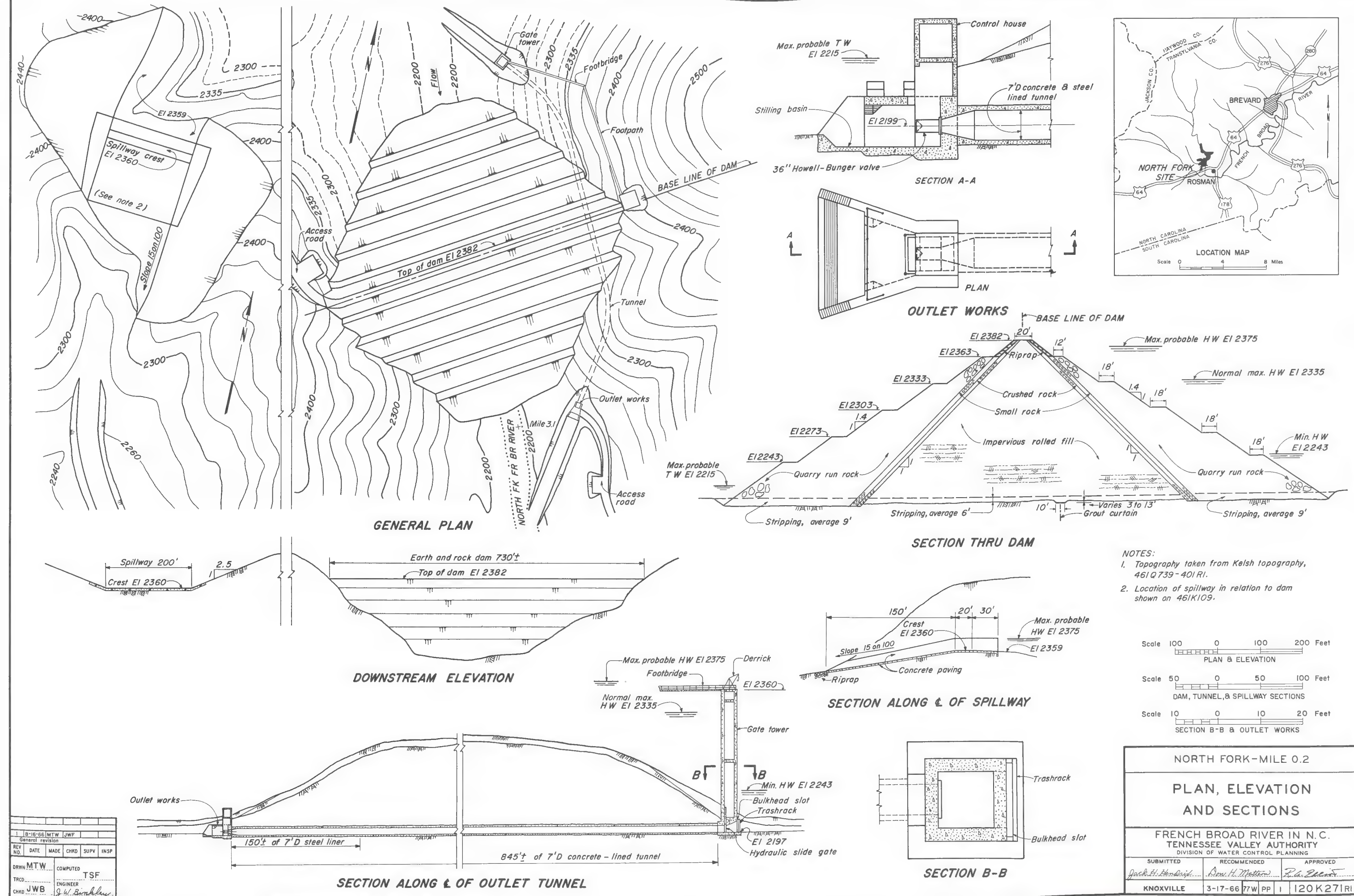
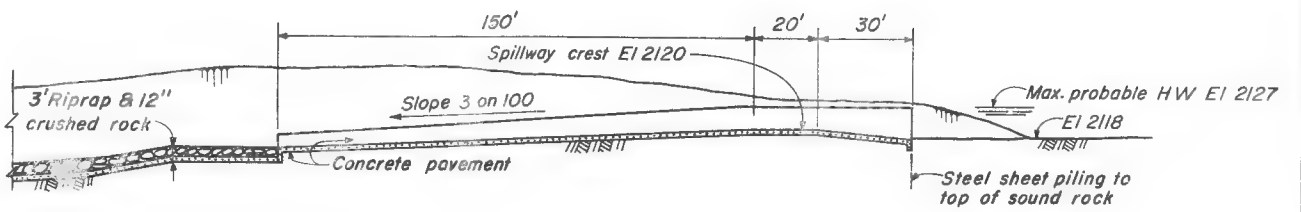
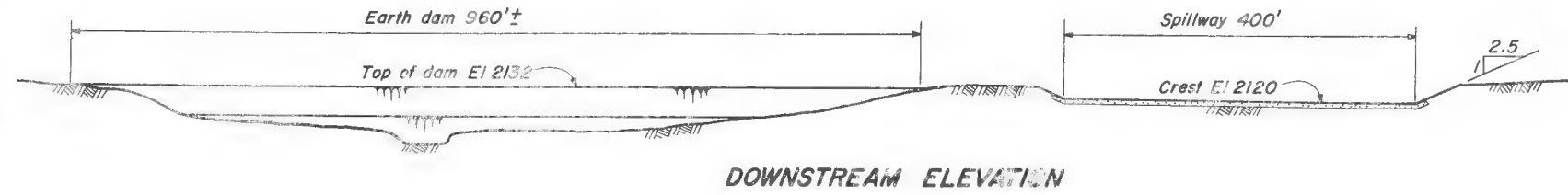
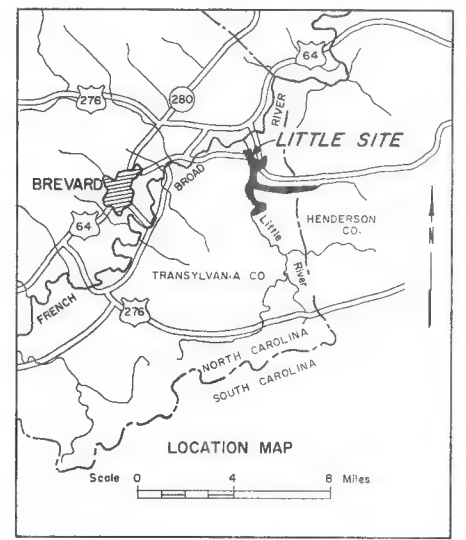
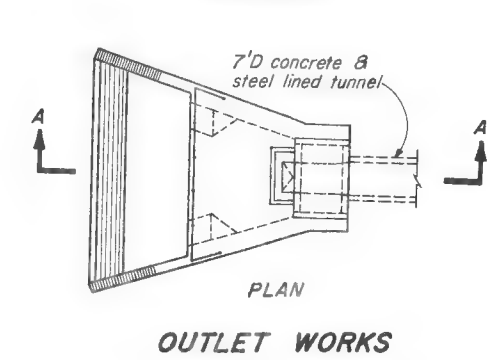
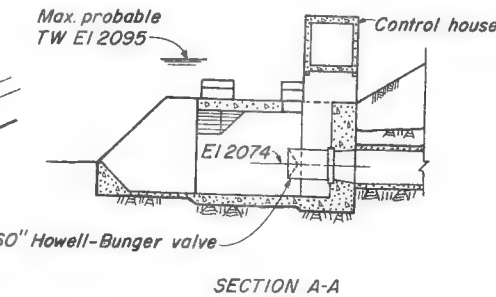
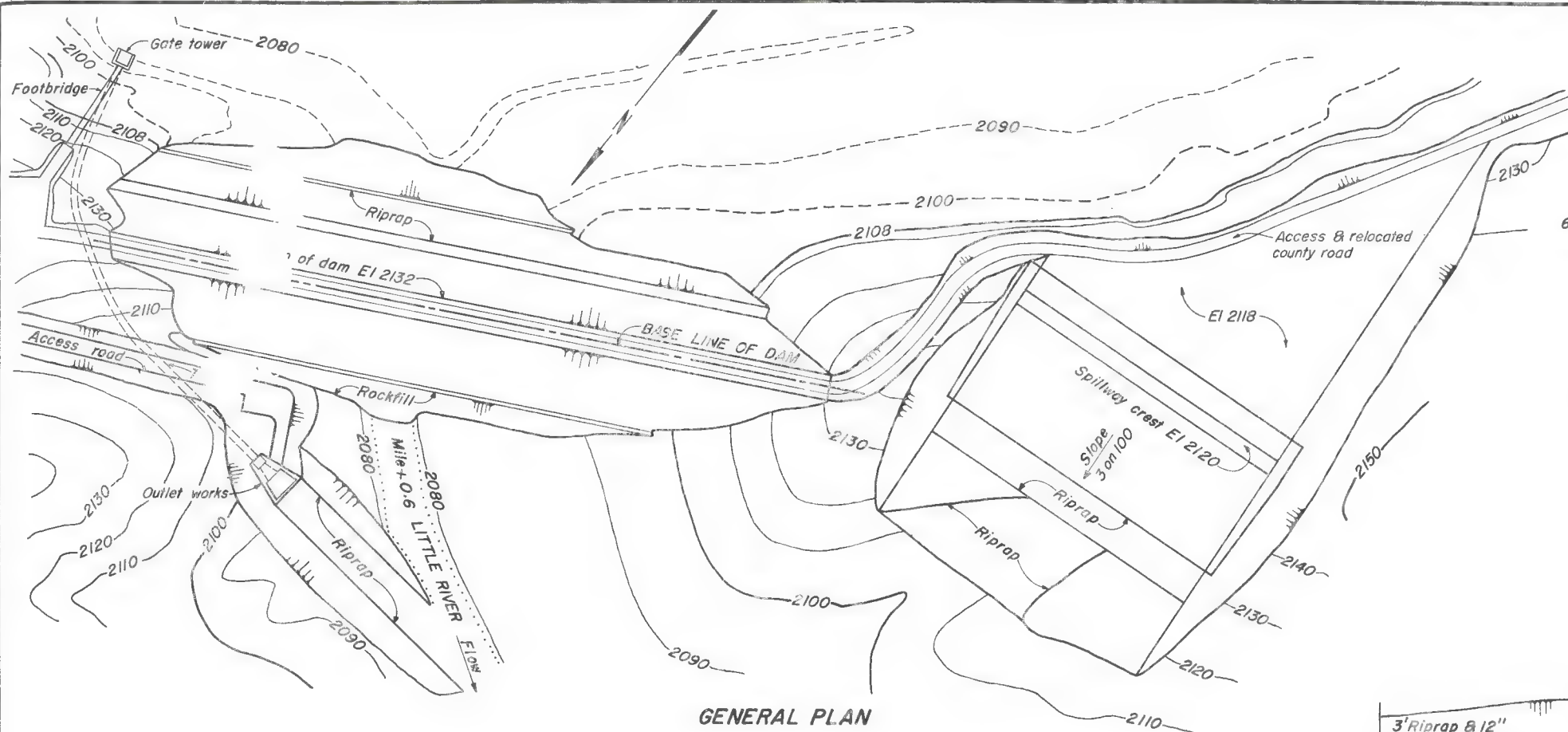


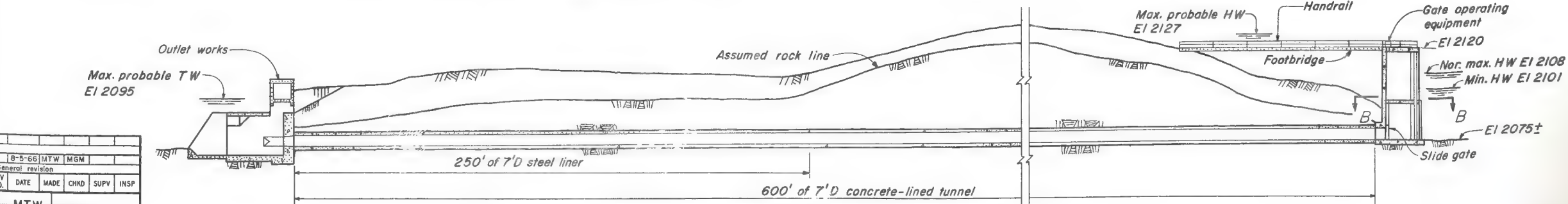
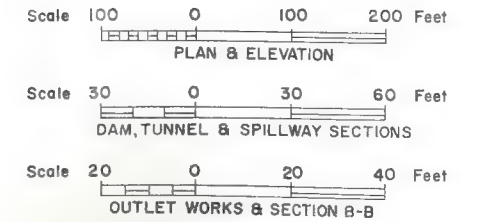
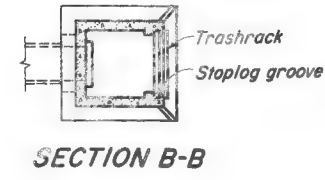
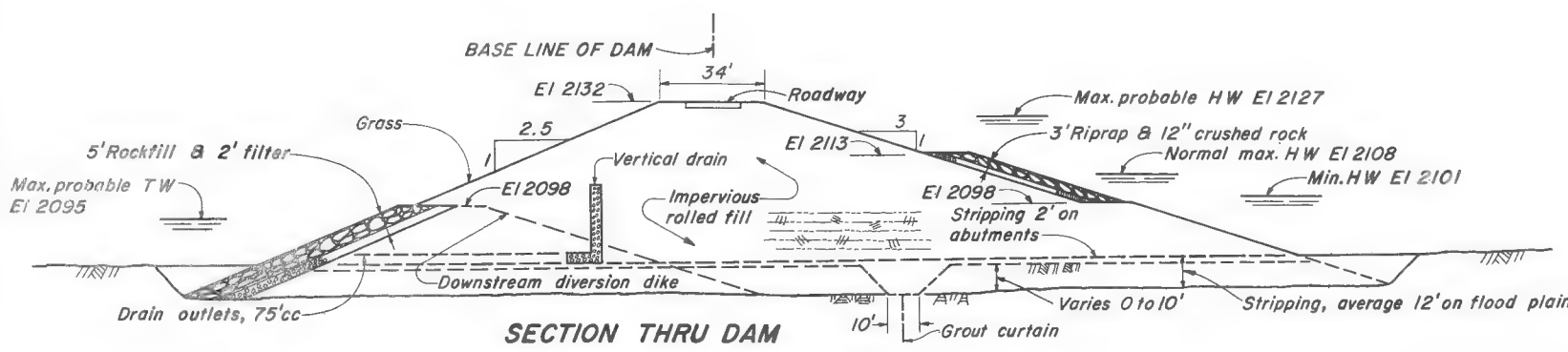


Figure 16 - LITTLE RIVER DAM SITE, LOOKING UPSTREAM

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NOTE:
1. Topography taken from Kelsh topography, 462Q557-237.
2. Saddle dam shown on dwg 46/K111.



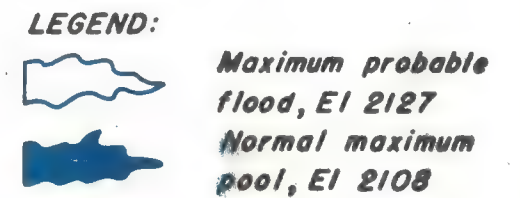
LITTLE RIVER-MILE 0.6

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack H. Hendricks	Don H. Mathews	R. A. Egan
KNOXVILLE	3-17-66 77P PP	1 120 K 273 RI

1	8-5-66	MTW	MGM			
General revision						
REV	DATE	MADE	CHKD	SUPV	INSP	
DRWN	MTW	COMPUTED				
TRCD		ENGINEER				
CHKD	MGM	MAJOR				



Scale 1000 0 1000 2000 Feet

LITTLE RIVER-MILE 0.6

RESERVOIR MAP

FRENCH BROAD RIVER IN N. C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

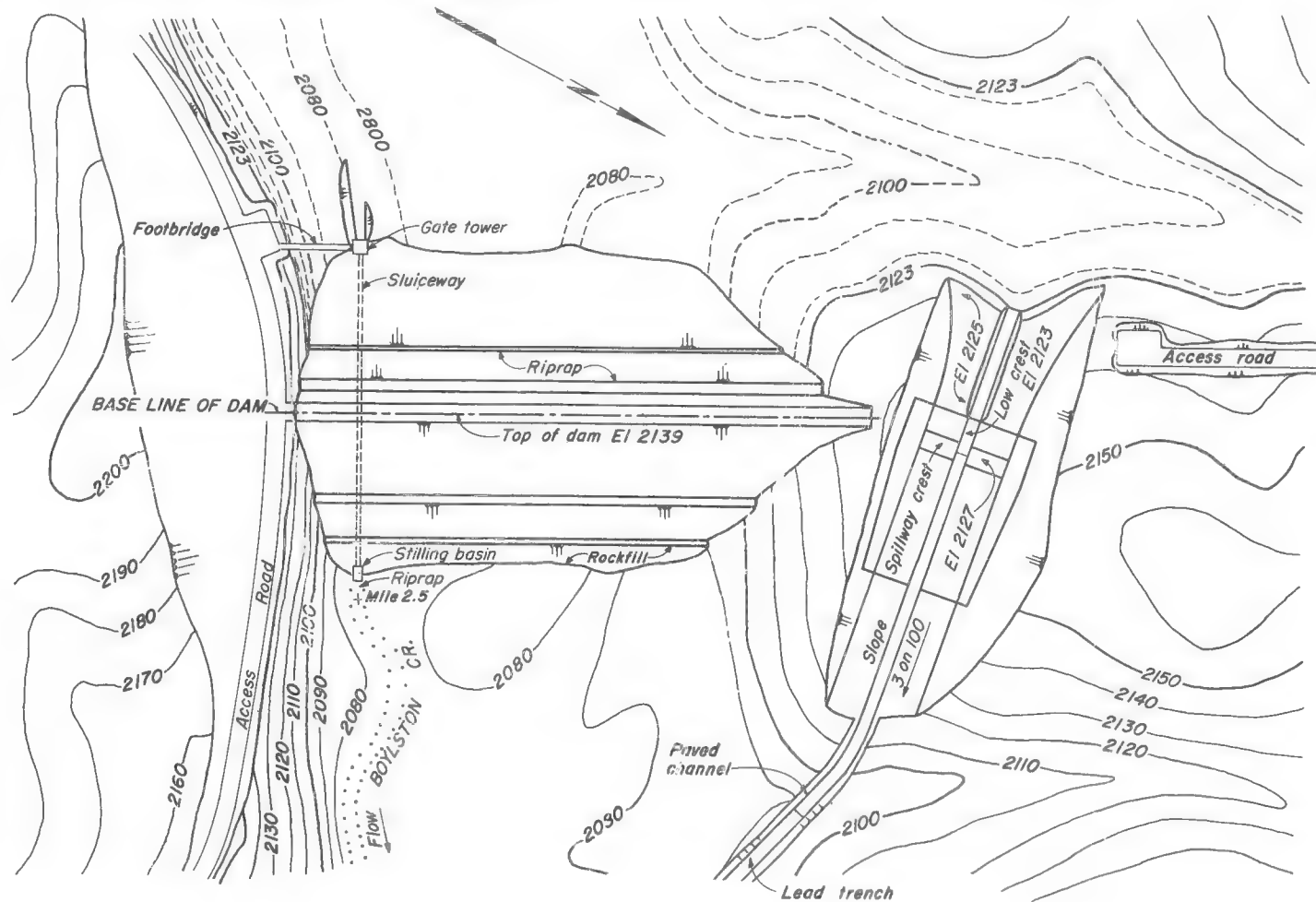
SUBMITTED <i>H. H. H. H.</i>	RECOMMENDED <i>Don H. H. H.</i>	APPROVED <i>R. A. H. H.</i>
KNOXVILLE	2-1-66 77P PP 1	453B302

REV NO.	DATE	MADE	CHNG	SUPY	INSP
DRAWN _____			COMPUTED _____		
TRCD _____			ENGINEER _____		
CHNG _____			M. G. Wilson		

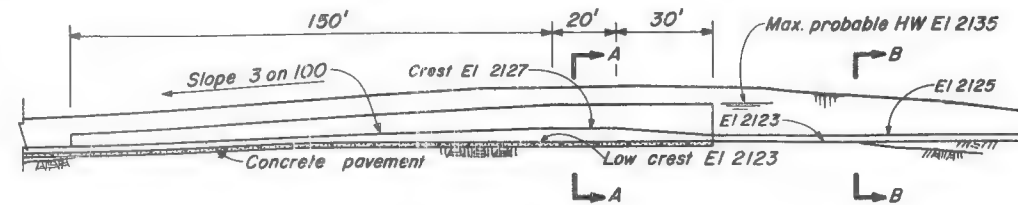


Figure 17 - BOYLSTON CREEK DAM SITE, LOOKING DOWNSTREAM

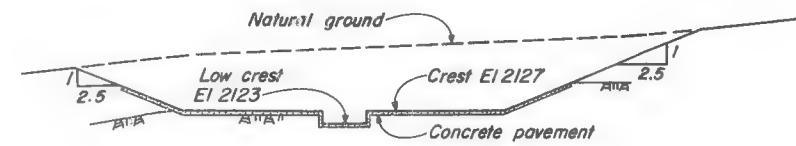
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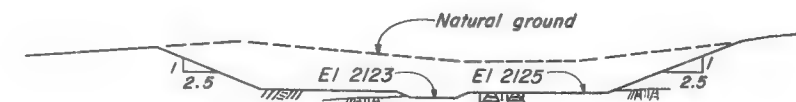
GENERAL PLAN



SECTION ALONG A

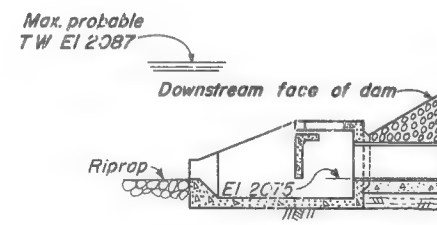


SECTION A-A

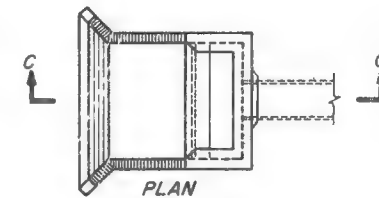


SECTION B-B

SPILLWAY



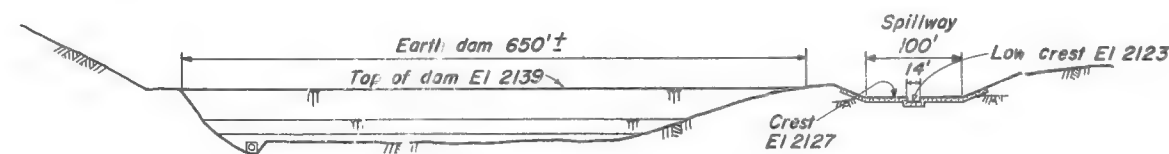
SECTION C-C



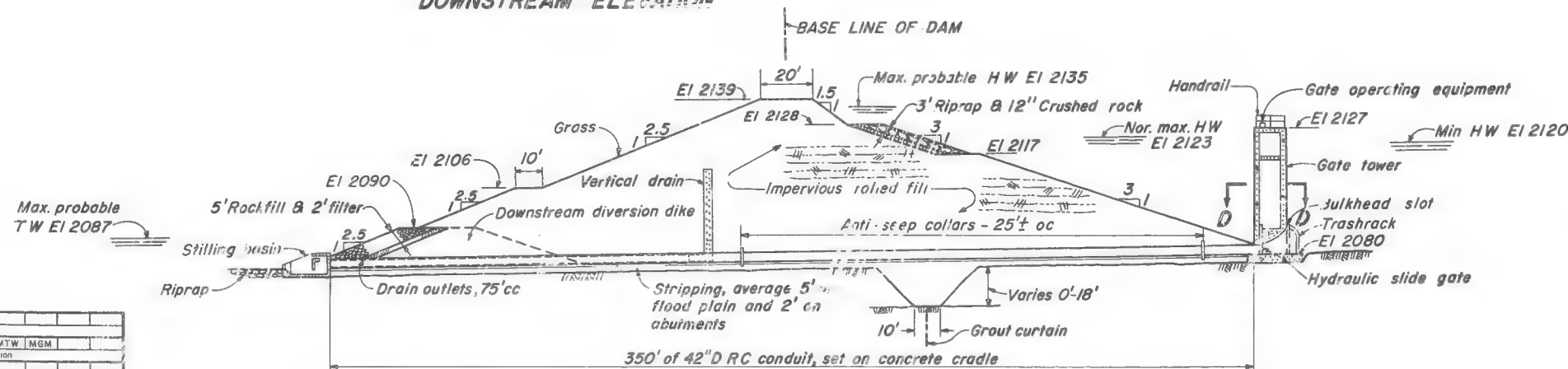
PLAN

STILLING BASIN

NOTE:
Topography taken from Kelsh topography,
461P691-B.



DOWNSTREAM ELEVATION

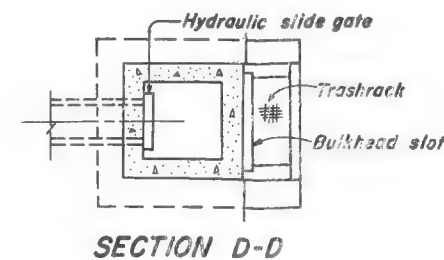


SECTION THRU DAM ALONG C OF SLUICeway

Scale 100 0 100 200 Feet
PLAN & ELEVATION

Scale 30 0 30 60 Feet
DAM & SPILLWAY SECTIONS

Scale 10 0 10 20 Feet
STILLING BASIN & SECTION D-D



SECTION D-D

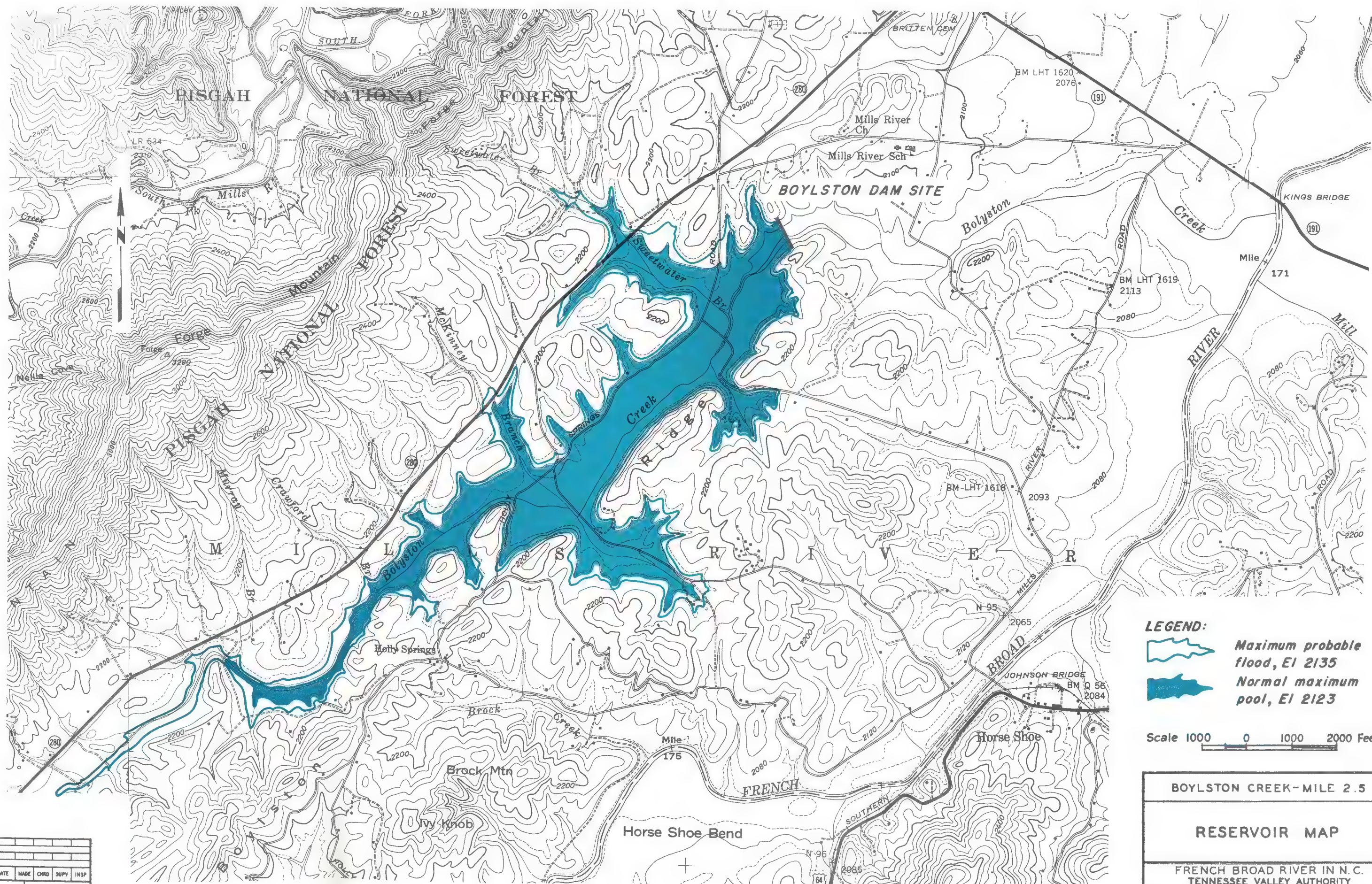
BOYLSTON CREEK-MILE 2.5

PLAN, ELEVATION
AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jan. 11, 1966	Jan. 11, 1966	Jan. 11, 1966
KNOXVILLE	3-17-66	77M PP 1
		120 K 274 RI

DRWN	MTW	COMPUTED	TSG
TRCD		ENGINEER	
CHRD	MGM		



LEGEND:



Maximum probable
flood, EI 2135
Normal maximum
pool, EI 2123

Scale 1000 0 1000 2000 Feet

BOYLSTON CREEK-MILE 2.5

RESERVOIR MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

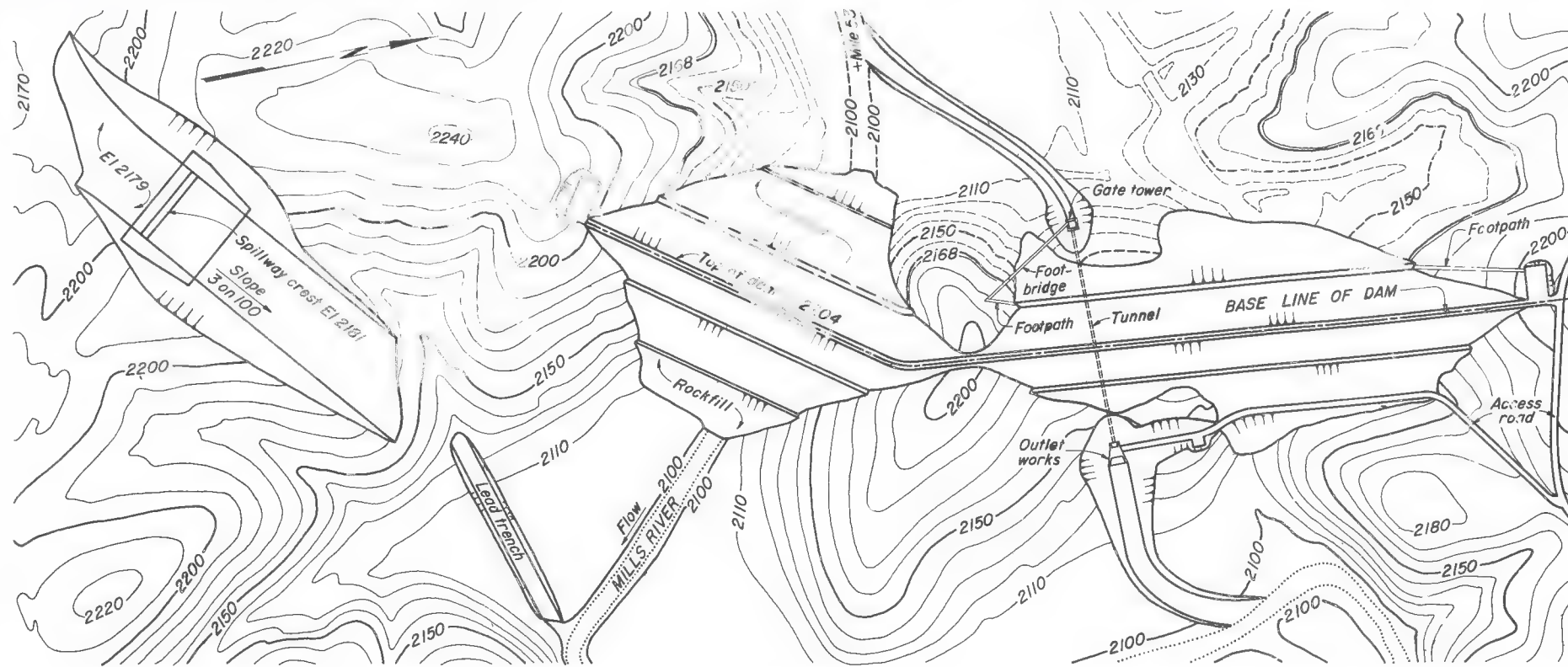
SUBMITTED	RECOMMENDED	APPROVED
<i>[Signature]</i>	<i>[Signature]</i>	<i>[Signature]</i>
KNOXVILLE	2-1-66 7M PP 1	453B303

REV	DATE	MADE	CHKD	SUPV	INSP
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100					



Figure 18 - MILLS RIVER DAM SITE, LOOKING UPSTREAM

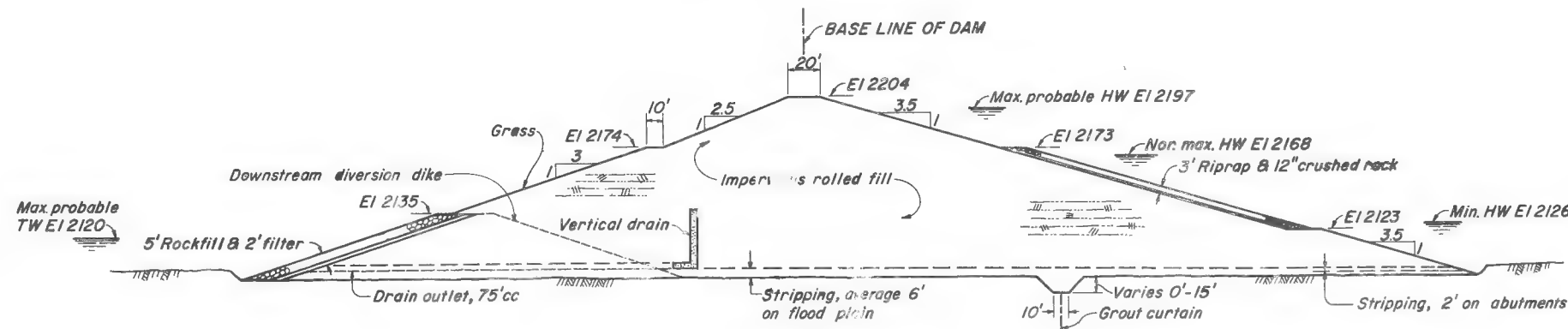
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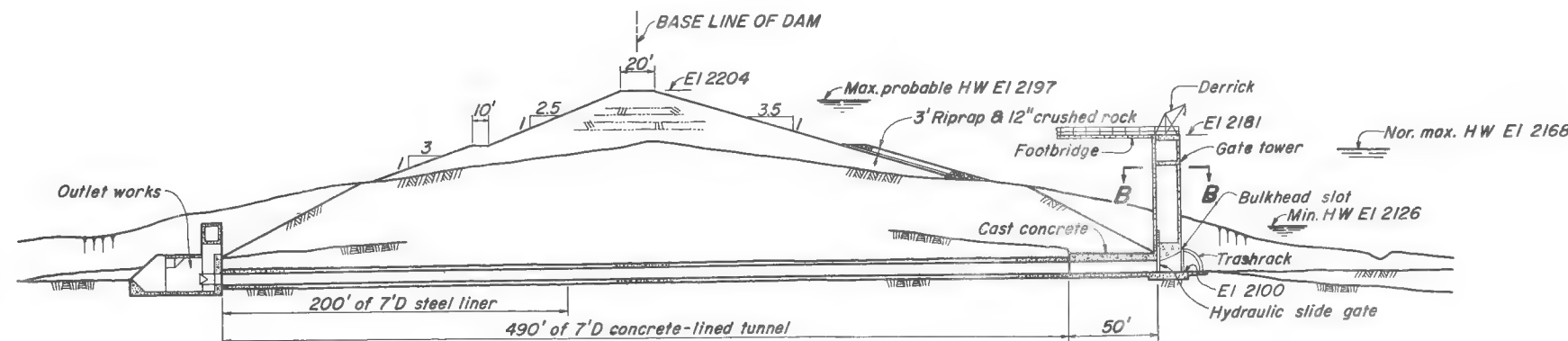
GENERAL PLAN



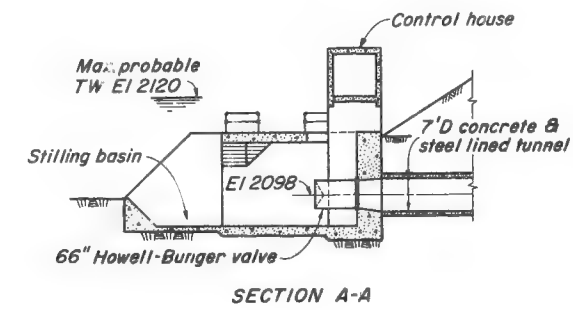
DOWNSTREAM ELEVATION



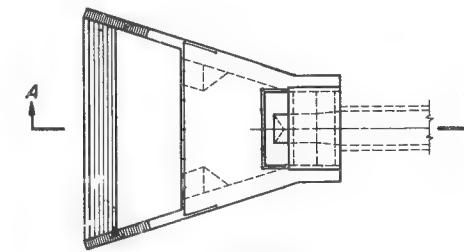
SECTION THRU DAM



SECTION ALONG & OF OUTLET TUNNEL

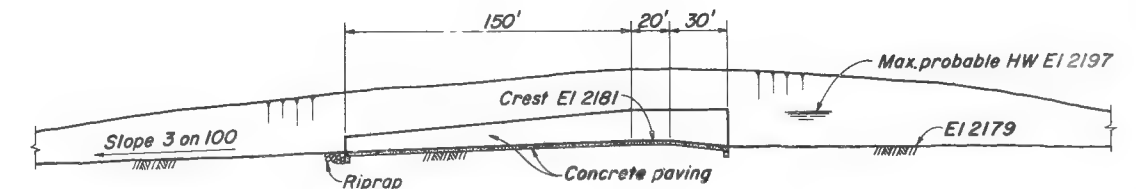


SECTION A-A



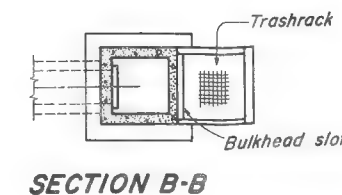
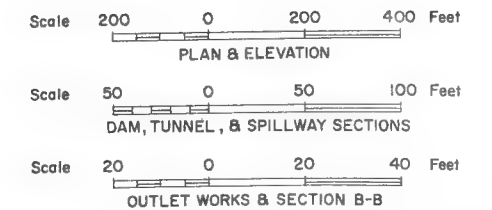
PLAN

OUTLET WORKS



SECTION ALONG & OF SPILLWAY

NOTE:
Topography taken from Kelsh topography,
462 P503-201.



SECTION B-B

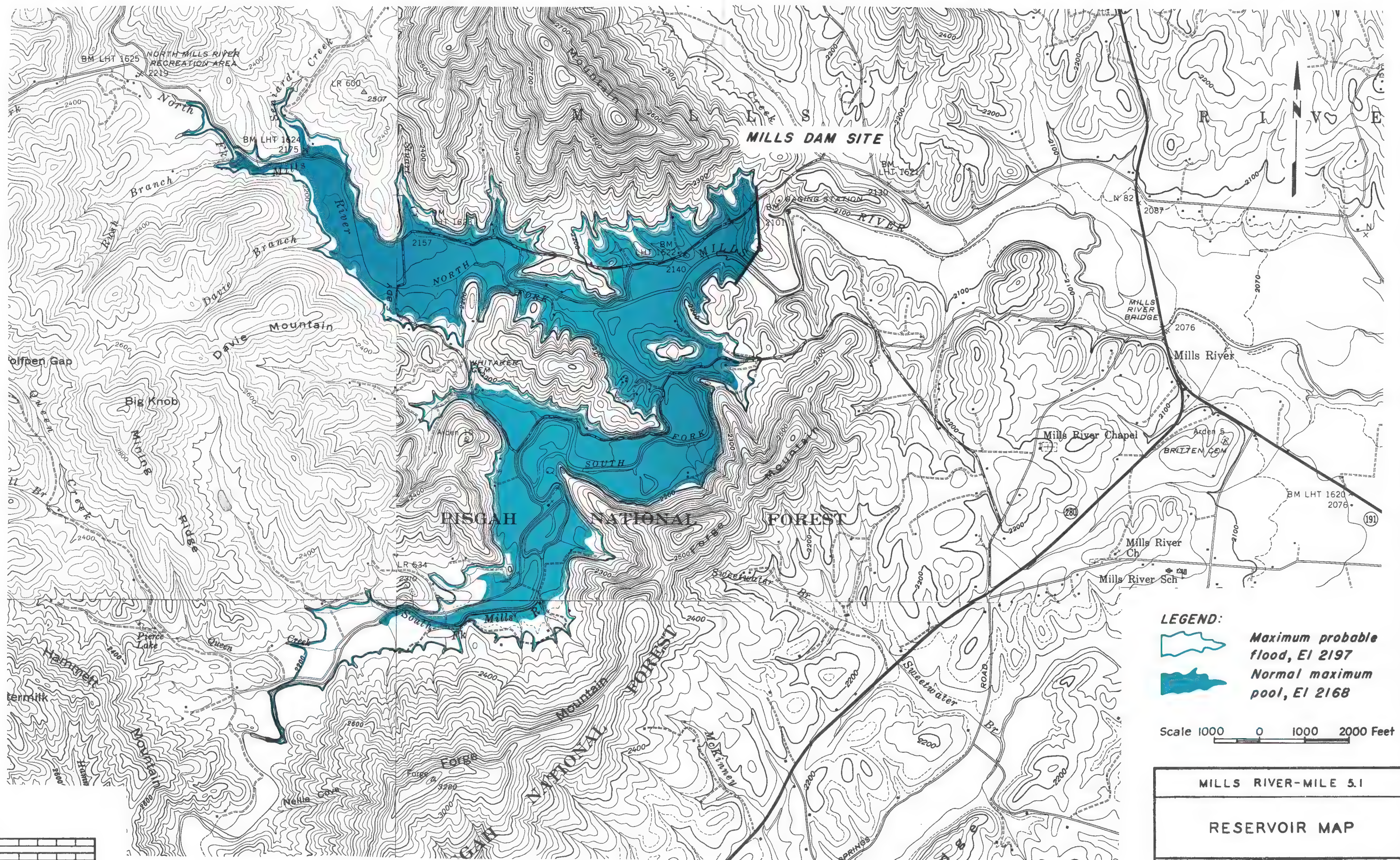
MILLS RIVER-MILE 5.1

PLAN, ELEVATION
AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
<i>Jack H. Hendrix</i>	<i>Paul H. Matton</i>	<i>Paul H. Matton</i>
KNOXVILLE	3-17-66 77L PP 1	120 K 275R1

REV. NO.	DATE	MADE	CHD	SUPY	INSP
1	8-16-66	NTW	JWF		
DRWN.	EH	COMPUTED	EH		
TRCD.		ENGINEER			
CHD.	JWB	J. W. Binkley			



LEGEND:

Scale 1000 0 1000 2000 Feet

MILLS RIVER-MILE 5.1

RESERVOIR MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED <i>J.H. Hendrix</i>	RECOMMENDED <i>Don H. Matheson</i>	APPROVED <i>R.H. Elliott</i>
KNOXVILLE	2-1-66	77L PP 1 453B304

REV	DATE	MADE	CHWD	SUPY	INSP
NO.					
DRAWN			COMPUTED		
TRCD			ENGINEER		
CHWD			<i>J. L. Bunkley</i>		

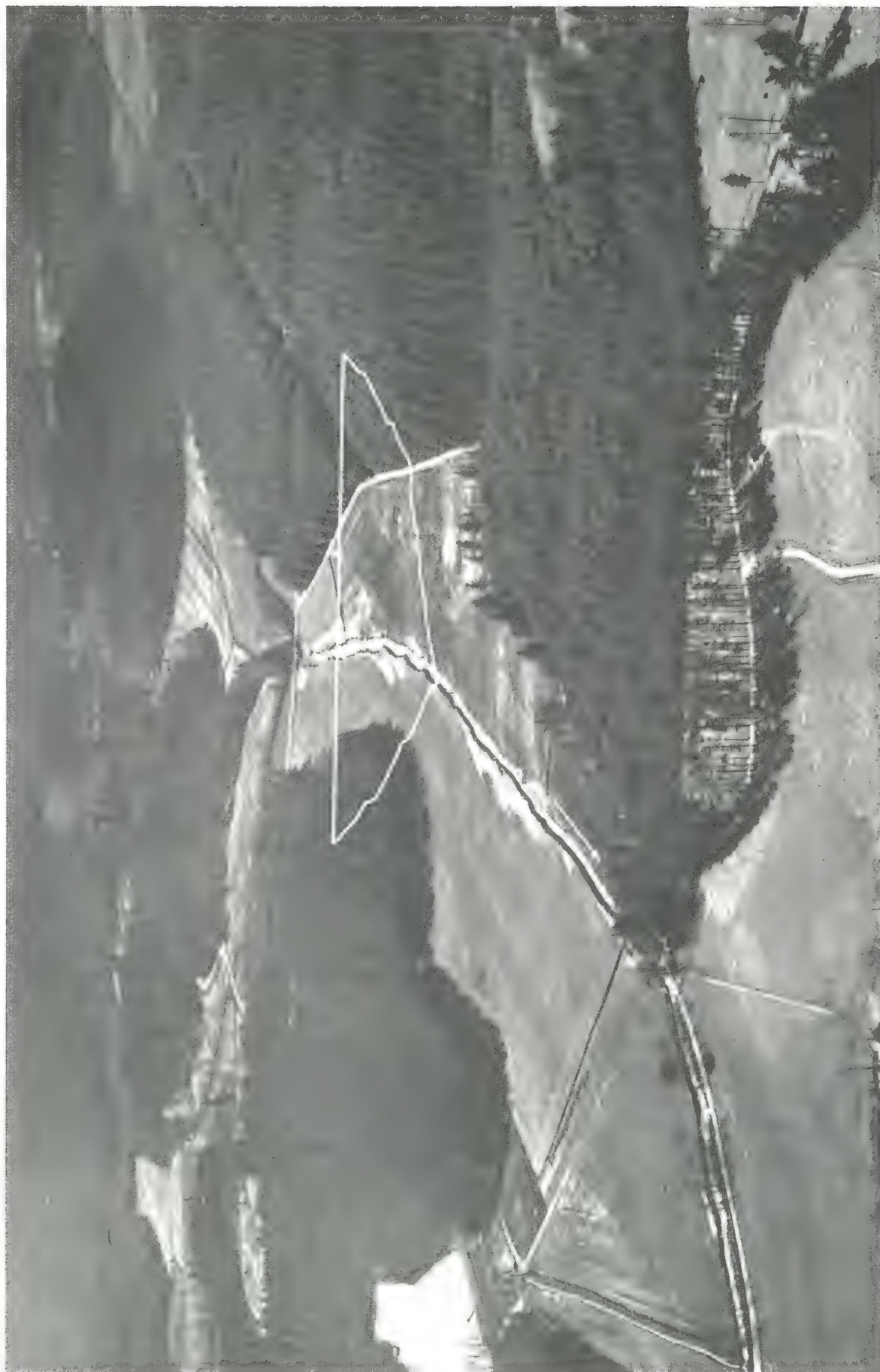
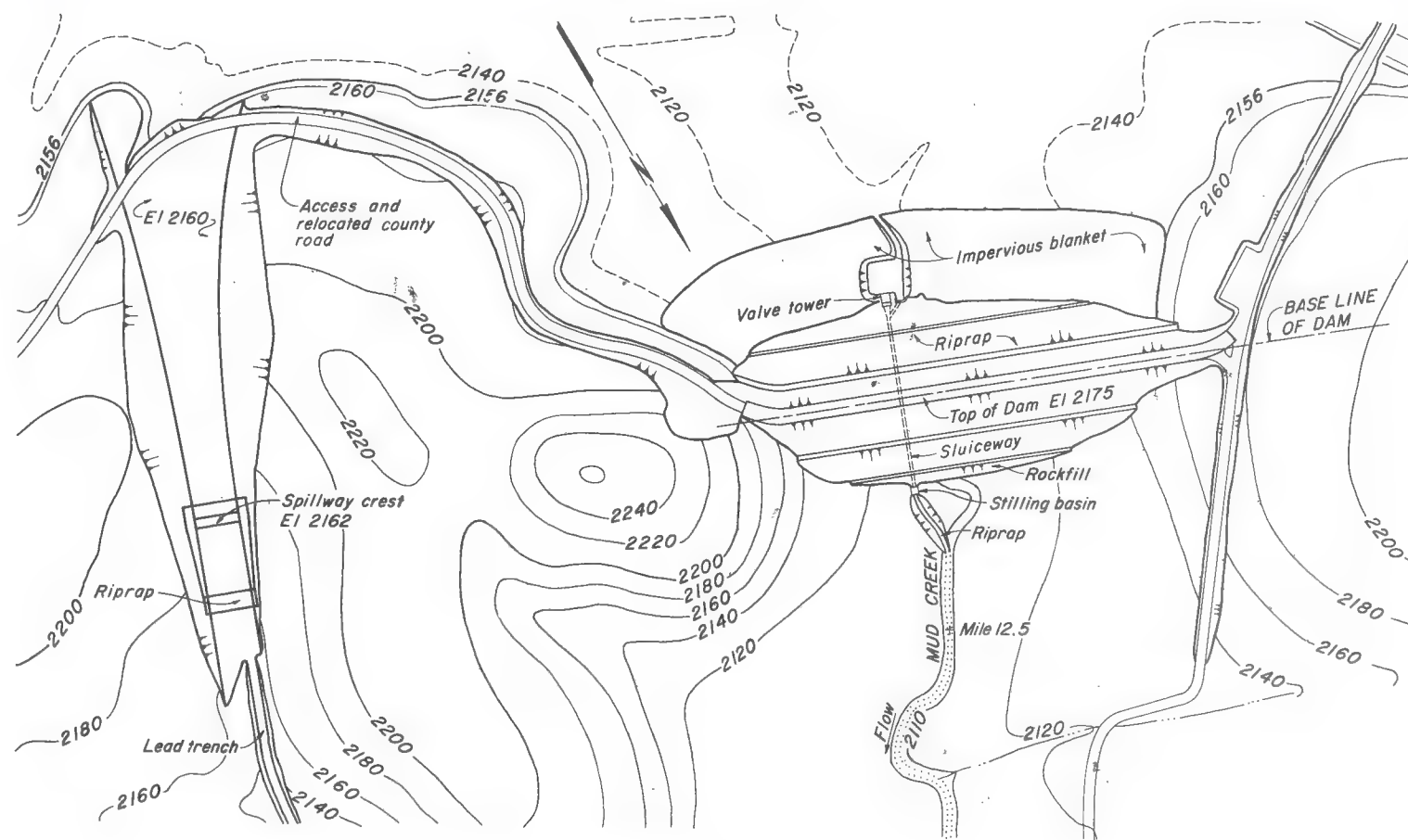


Figure 19 - MUD CREEK DAM SITE, LOOKING UPSTREAM

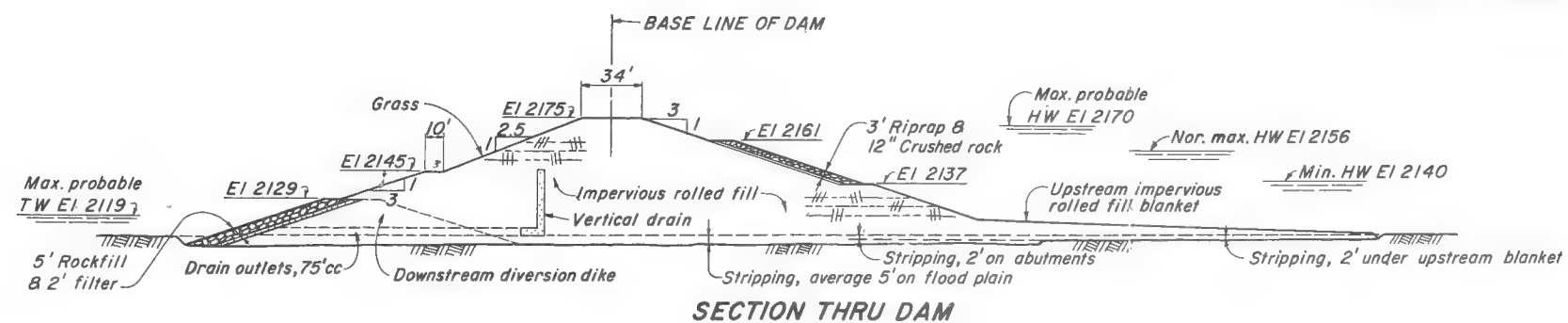
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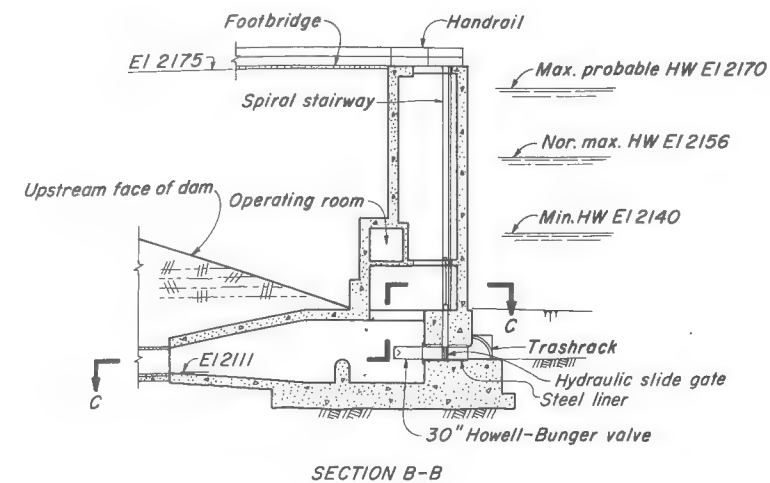
GENERAL PLAN



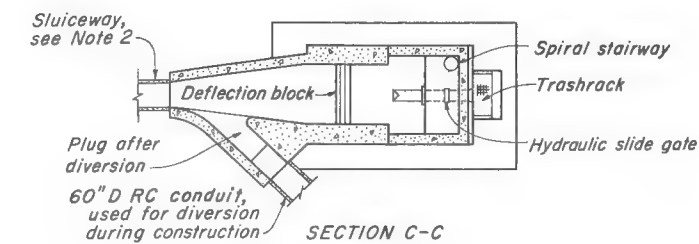
DOWNSTREAM ELEVATION



SECTION THRU DAM

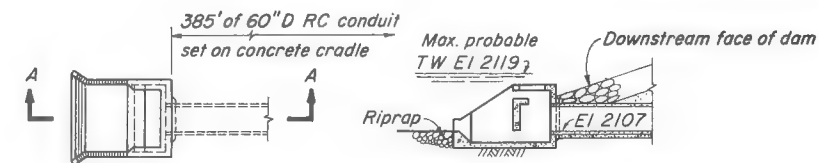


SECTION B-B



SECTION C-C

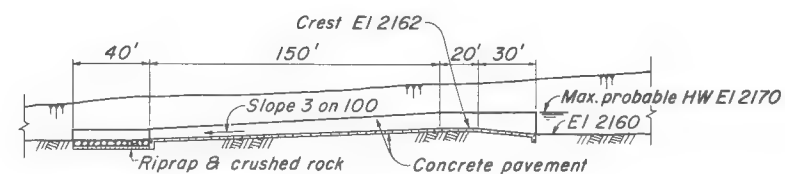
VALVE TOWER



PLAN

SECTION A-A

STILLING BASIN



SECTION ALONG E OF SPILLWAY

- NOTES:
1. Topography taken from Kelsh topography, 460 Q 618-401.
 2. Sluiceway provided with 9 antiseep collars, 25' cc.

Scale 200 0 200 400 Feet
PLAN & ELEVATION

Scale 50 0 50 100 Feet
DAM & SPILLWAY SECTIONS

Scale 20 0 20 40 Feet
STILLING BASIN & VALVE TOWER

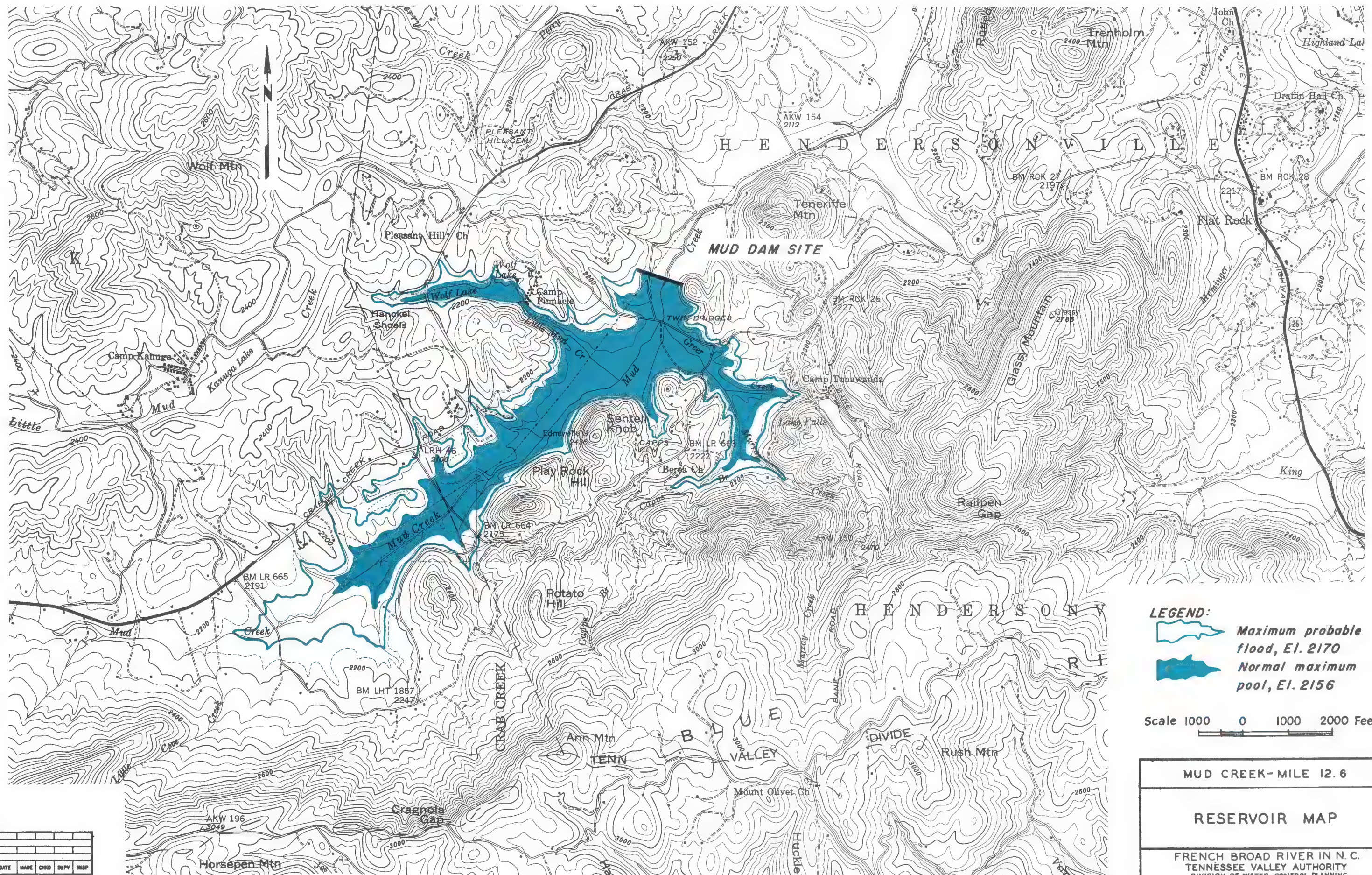
MUD CREEK-MILE 12.6

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack H. Finkling	Don H. Mattison	R. B. Bell
KNOXVILLE	3-17-66 77KPP	120 K 276RI

1	8-15-66	MTW	MGM			
General revision						
REV	DATE	MADE	CHKD	SUPV	INSP	
NO.						
DRWN	REH	COMPUTED				
TRCD		ENGINEER				
CHKD	MGM	Maurice G. Mahara				



LEGEND:

Maximum probable
flood, El. 2170
Normal maximum
pool, El. 2156

Scale 1000 0 1000 2000 Feet

MUD CREEK-MILE 12.6

RESERVOIR MAP

FRENCH BROAD RIVER IN N. C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

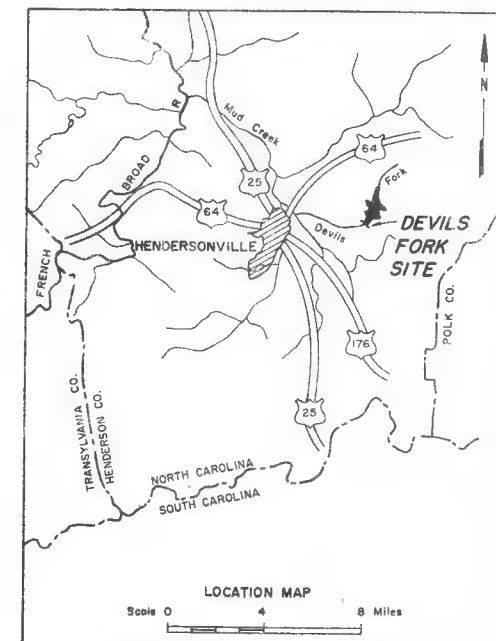
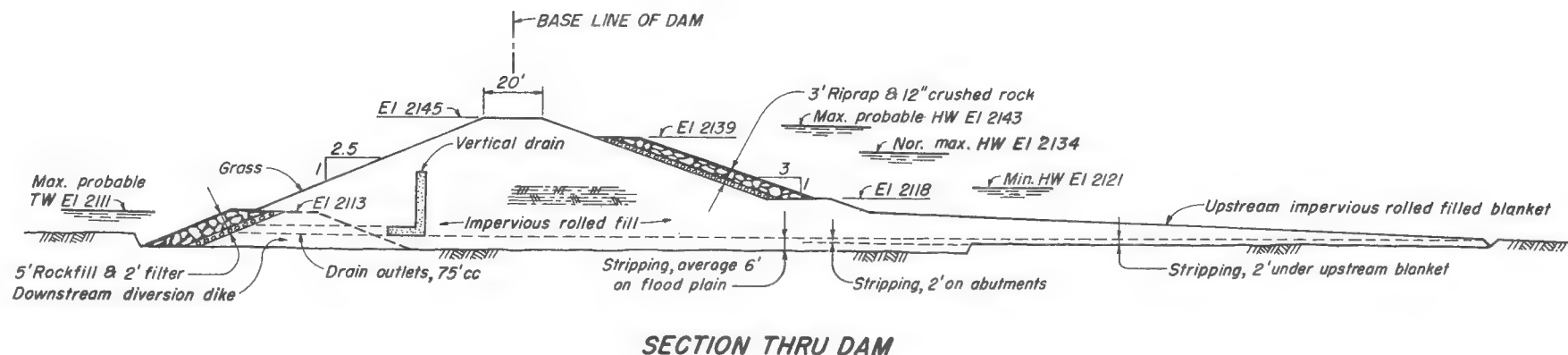
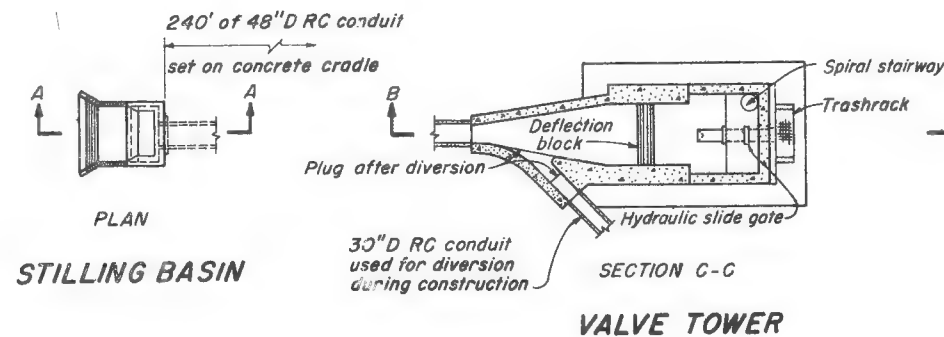
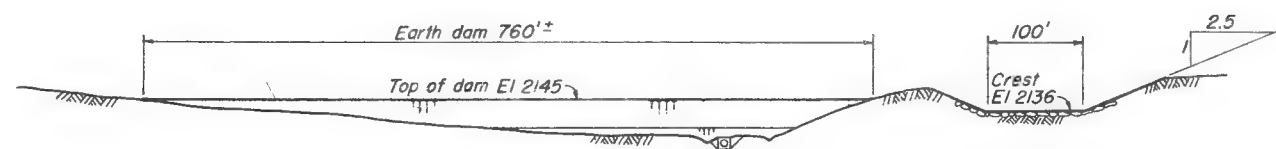
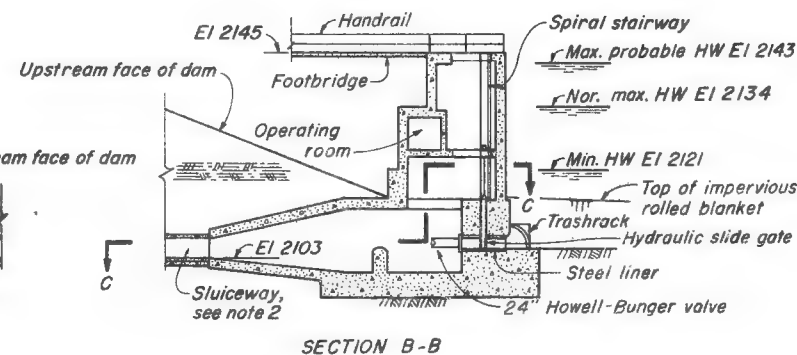
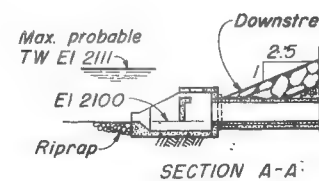
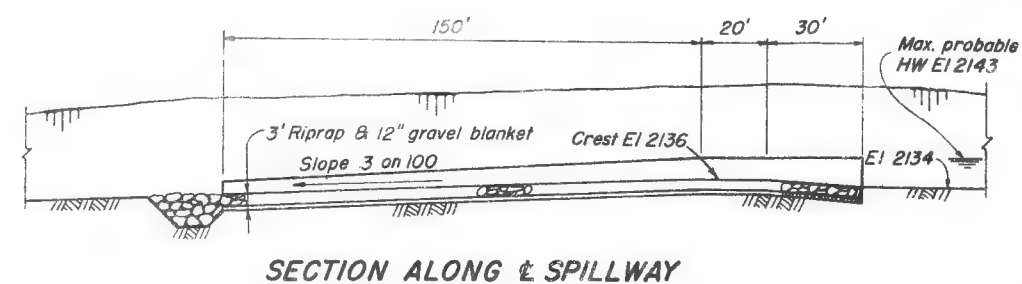
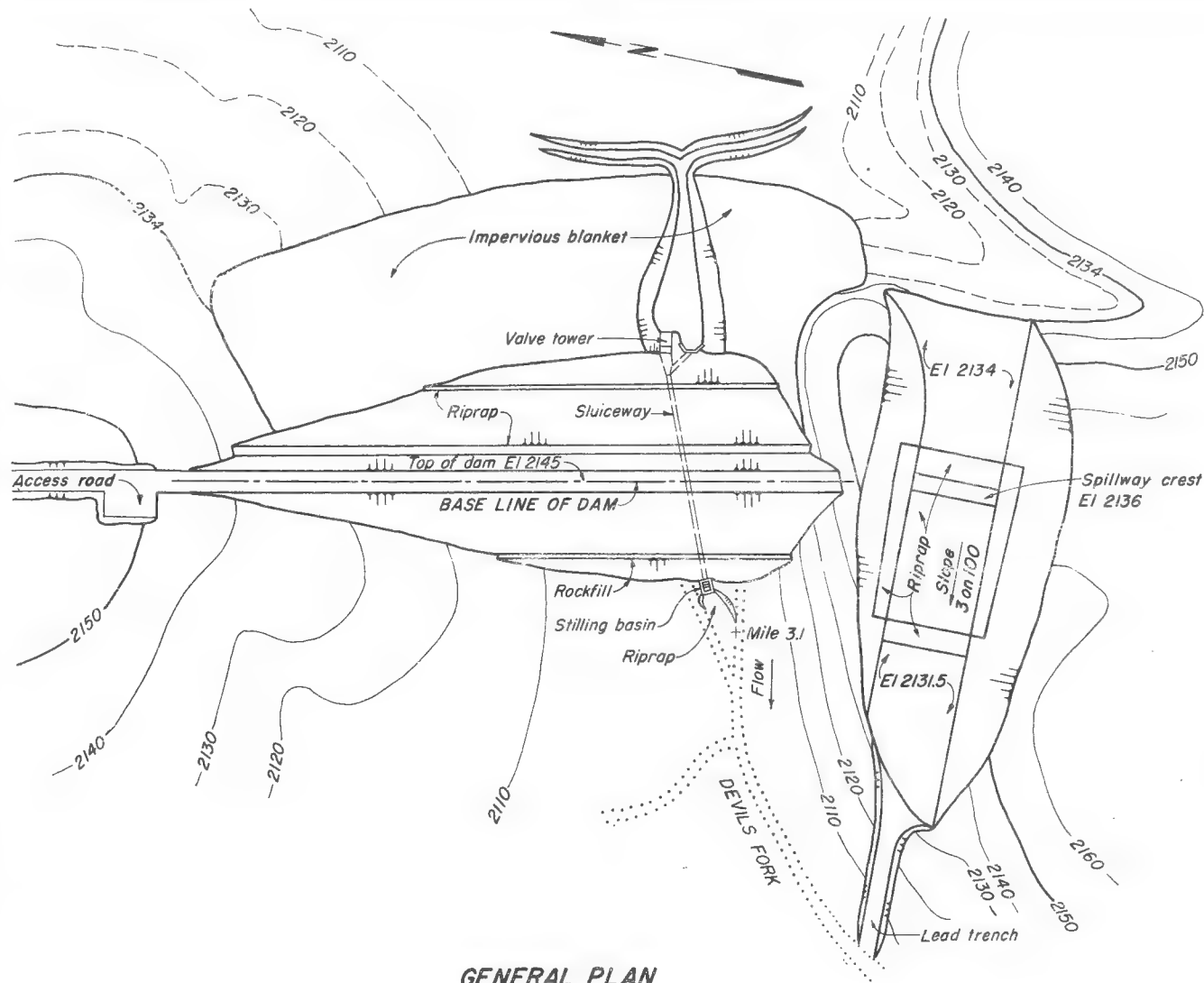
SUBMITTED <i>W. H. Hendrix</i>	RECOMMENDED <i>Orville H. Matheson</i>	APPROVED <i>R. A. ELLIS</i>
KNOXVILLE	2-1-66 77K PP 1	453B305

REV NO.	DATE	MADE	CHNG	SUPY	INSP
DRAWN _____			COMPUTED _____		
TRCD _____			ENGINEER _____		
CHNG _____			BY <u>M. G. McLean</u>		

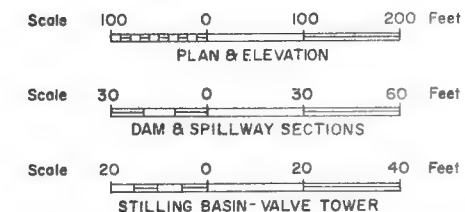


Figure 20 - DEVILS FORK DAM SITE, LOOKING UPSTREAM

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- NOTES:**
1. Topography taken from Kelsh topography, 460 Q617-401.
 2. Sluiceway provided with 7 antiseep collars 25'cc.



DEVILS FORK-MILE 3.1

PLAN, ELEVATION AND SECTIONS

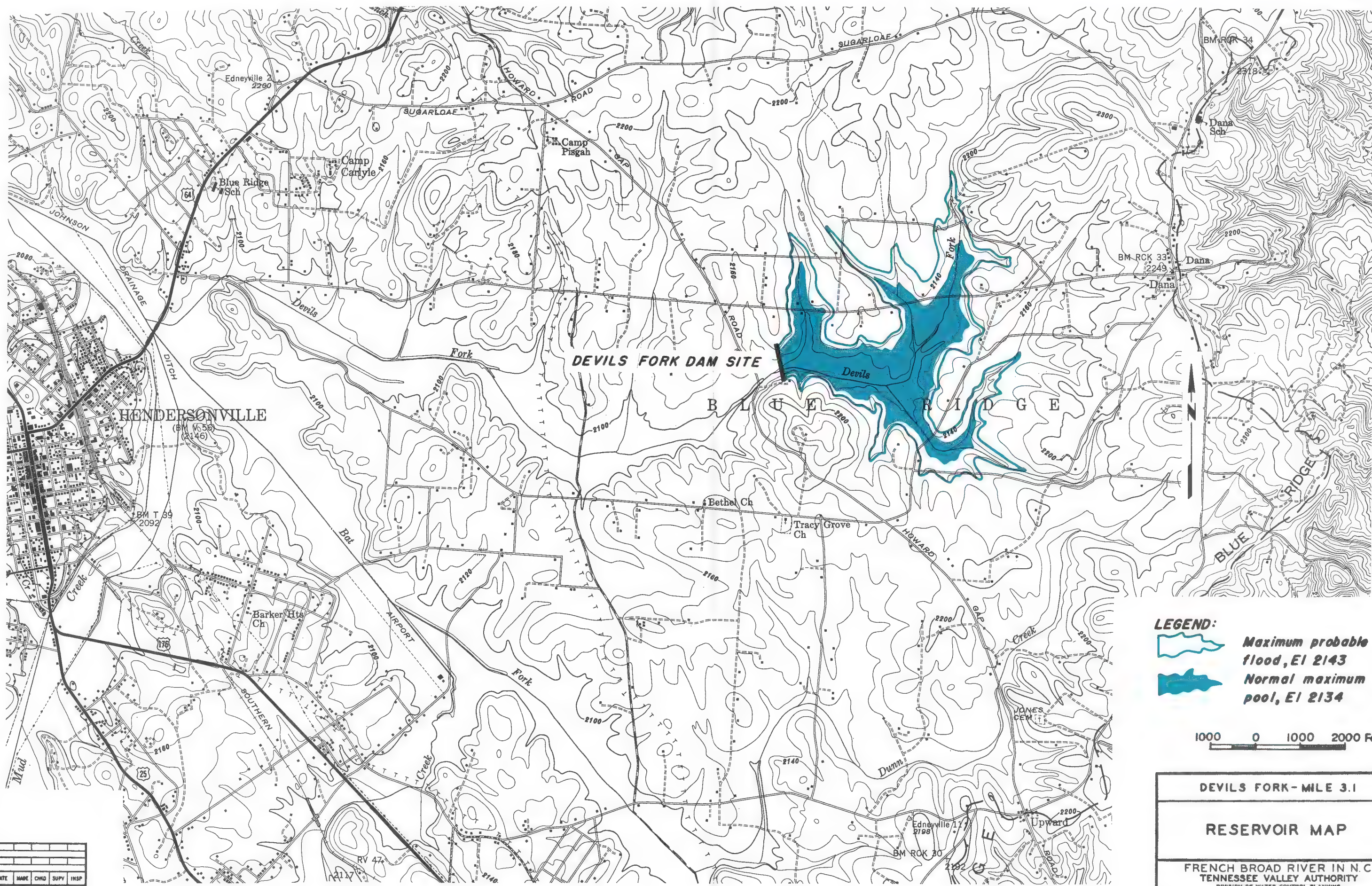
FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED RECOMMENDED APPROVED

John H. Hendrix *Randall M. Matthews* *John L. Zeller*

KNOXVILLE 3-17-66 77Y PP 1 120 K 277R1

18-22-66DJC	MGM
General revision	
REV. NO.	DATE
MADE	CHKD
SUPV	INSP
DRWN	DJC
COMPUTED	
TRCD	ENGINEER
CHKD	MGM
	Maurice G. Moore



DEVILS FORK - MILE 3.1

RESERVOIR MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNINGSUBMITTED: *W. H. M. R. R. R.* RECOMMENDED: *W. H. M. R. R. R.* APPROVED: *W. H. M. R. R. R.*

KNOXVILLE 2-1-66 77Y PP 1 453B306

REV	NO.	DATE	MADE	CHD	SUPV	INSP
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

DRAWN: _____

COMPUTED: _____

TRCD: _____

ENGINEER: _____

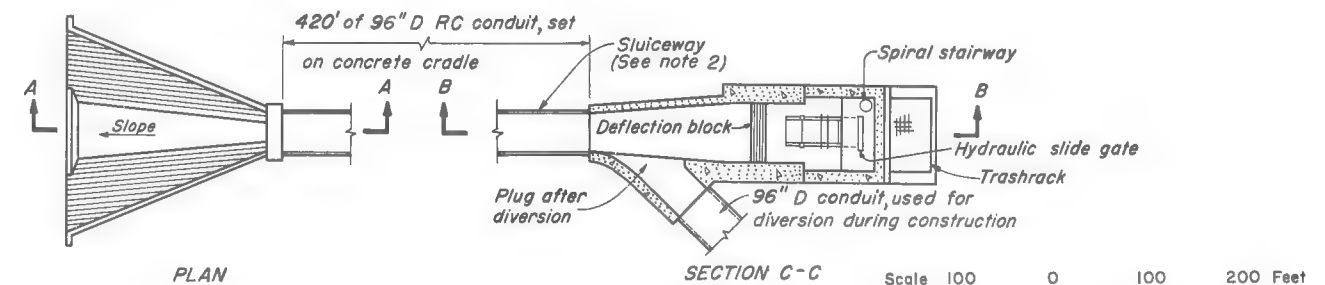
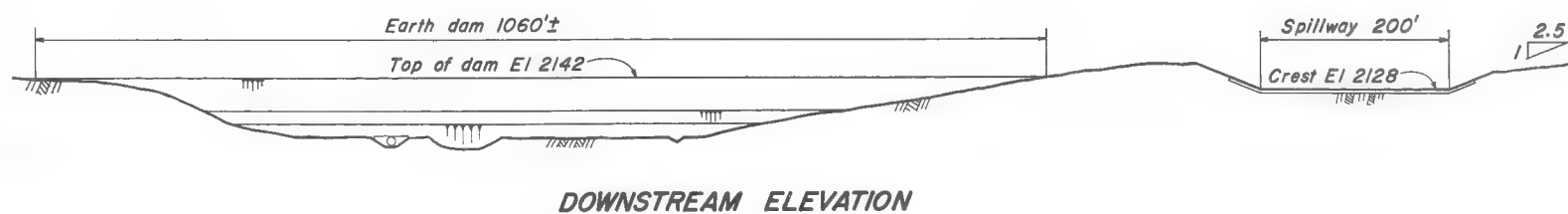
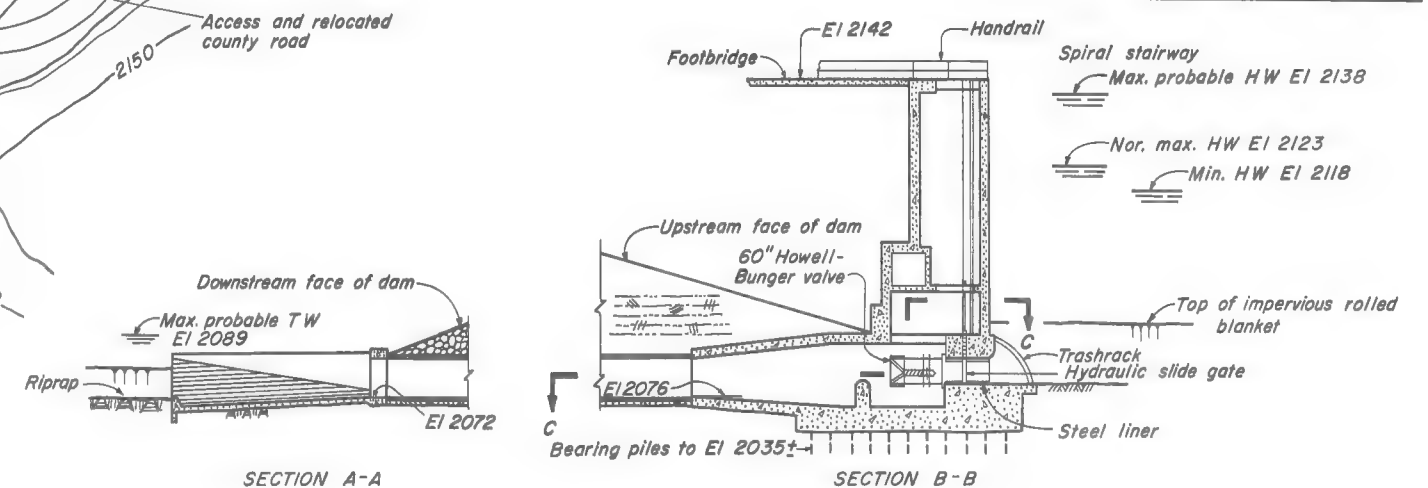
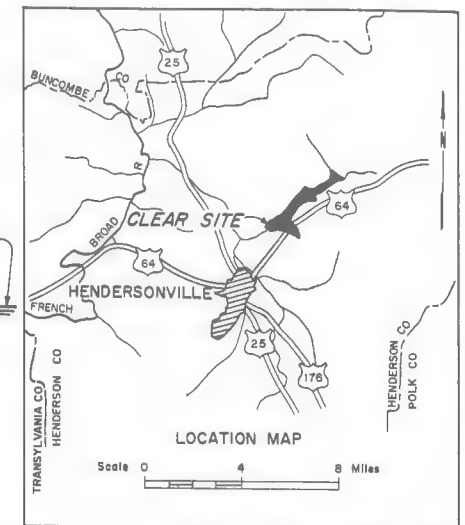
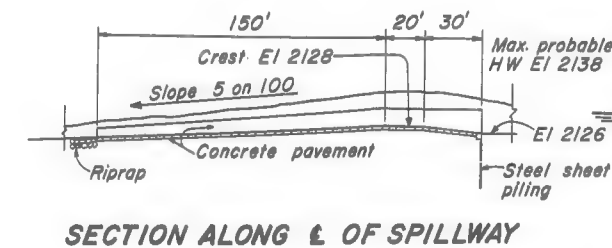
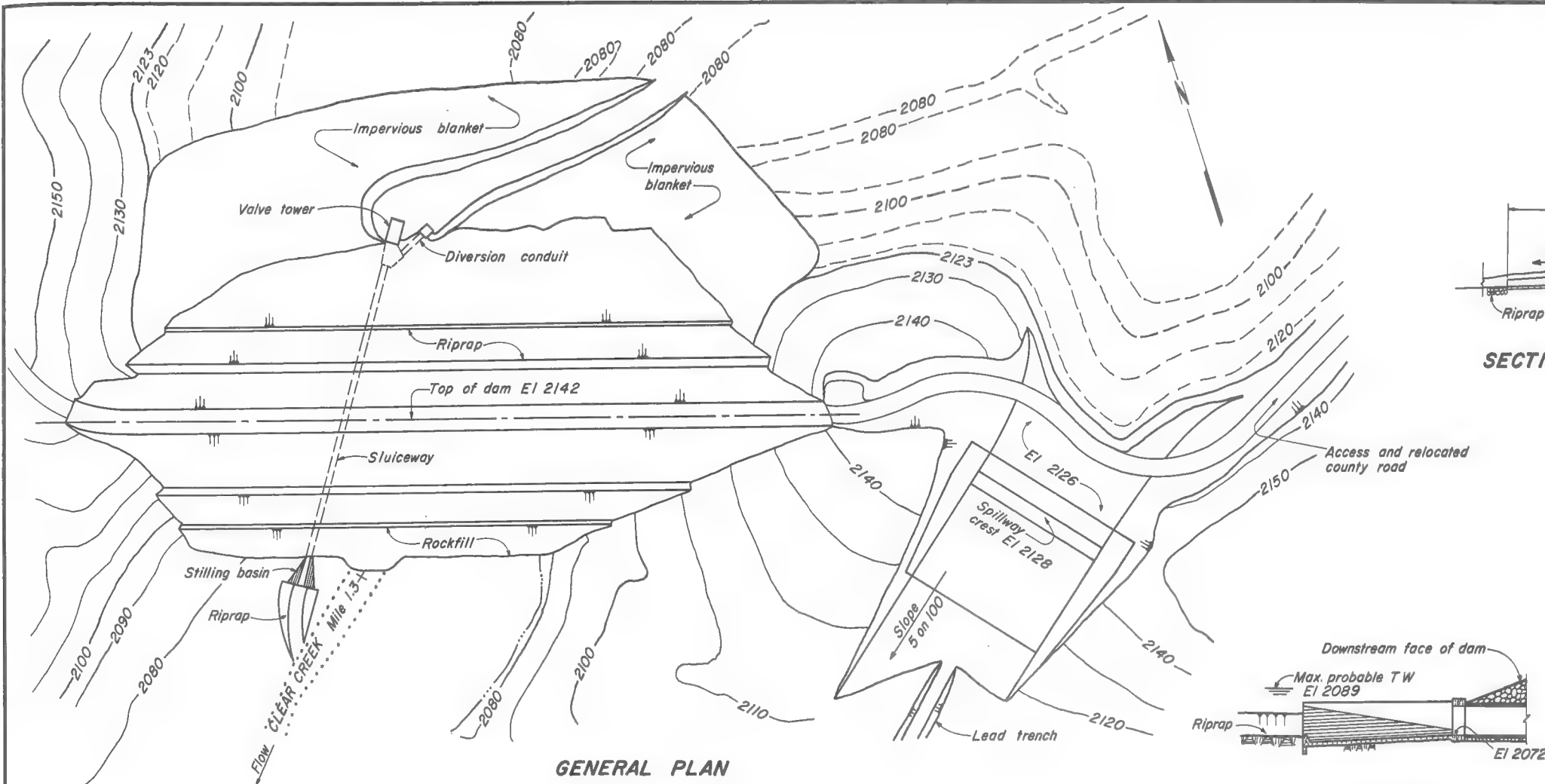
CHD: _____

M. G. Moore



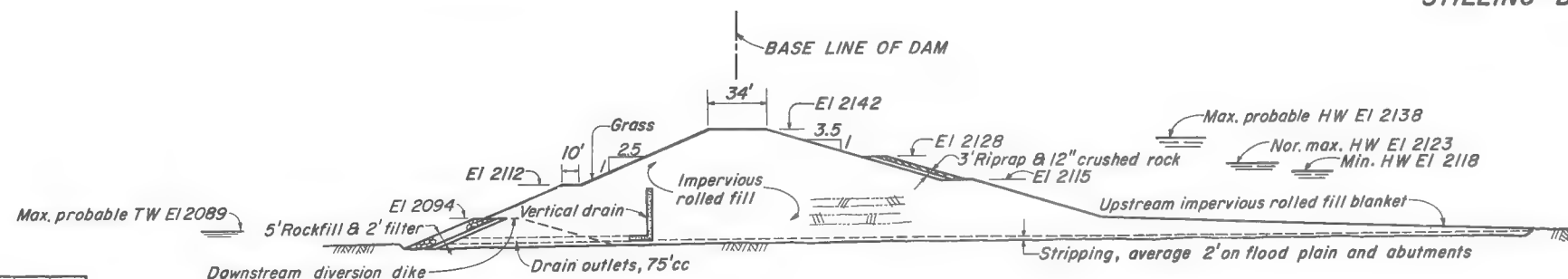
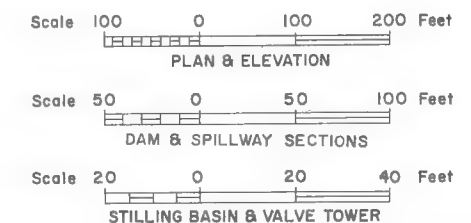
Figure 21 - CLEAR CREEK DAM SITE, LOOKING UPSTREAM

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STILLING BASIN

VALVE TOWER



- NOTES:**
- Topography taken from Kelsh topography, 461 Q 504-222.
 - Sluiceway provided with 10 antiseep collars 25' cc.

CLEAR CREEK - MILE 1.3

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

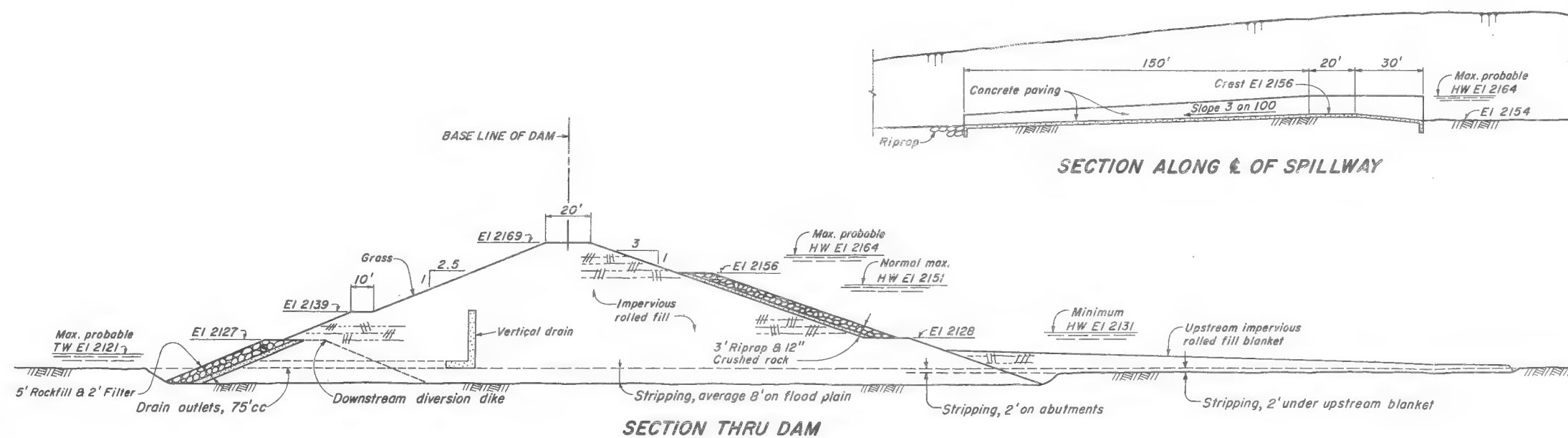
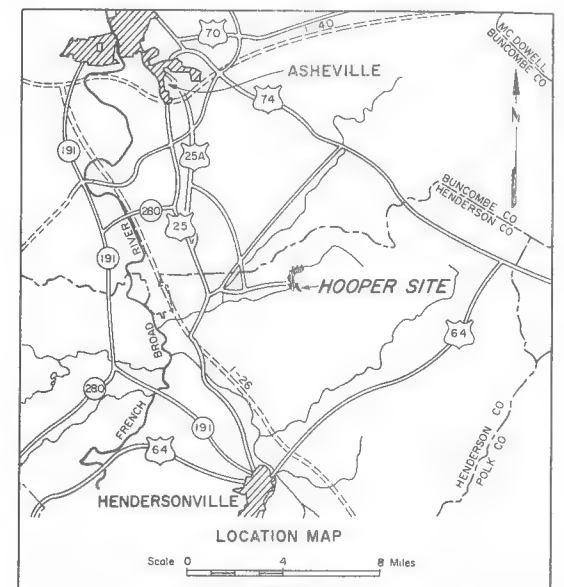
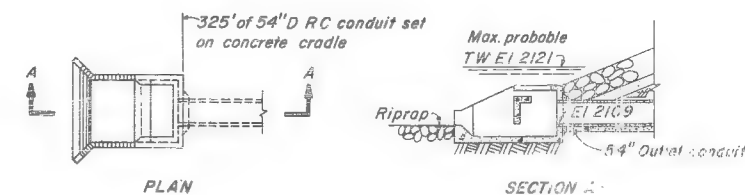
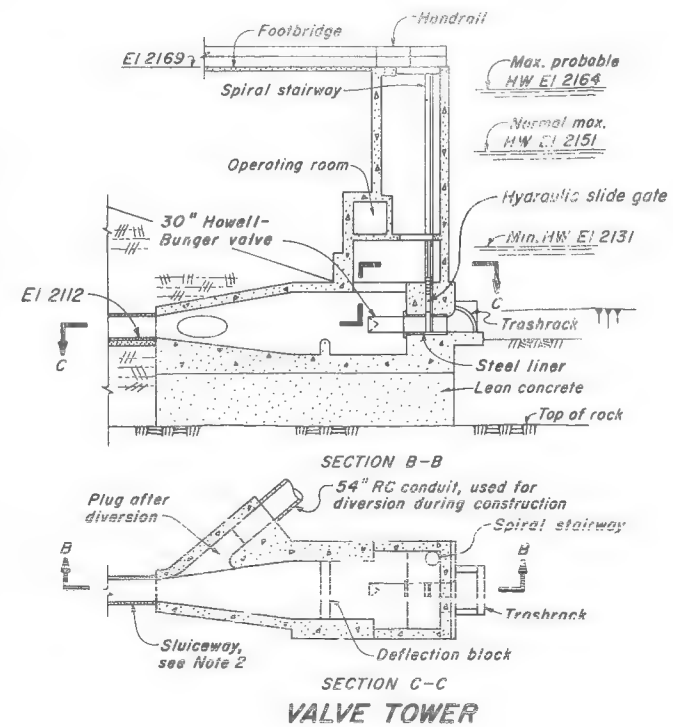
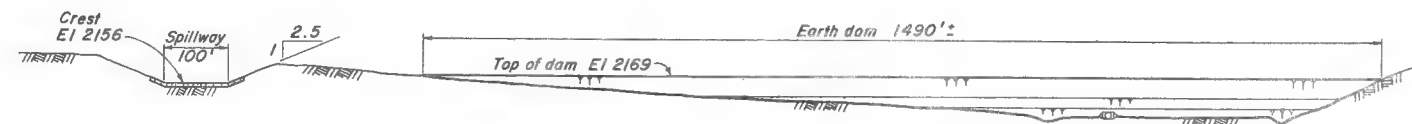
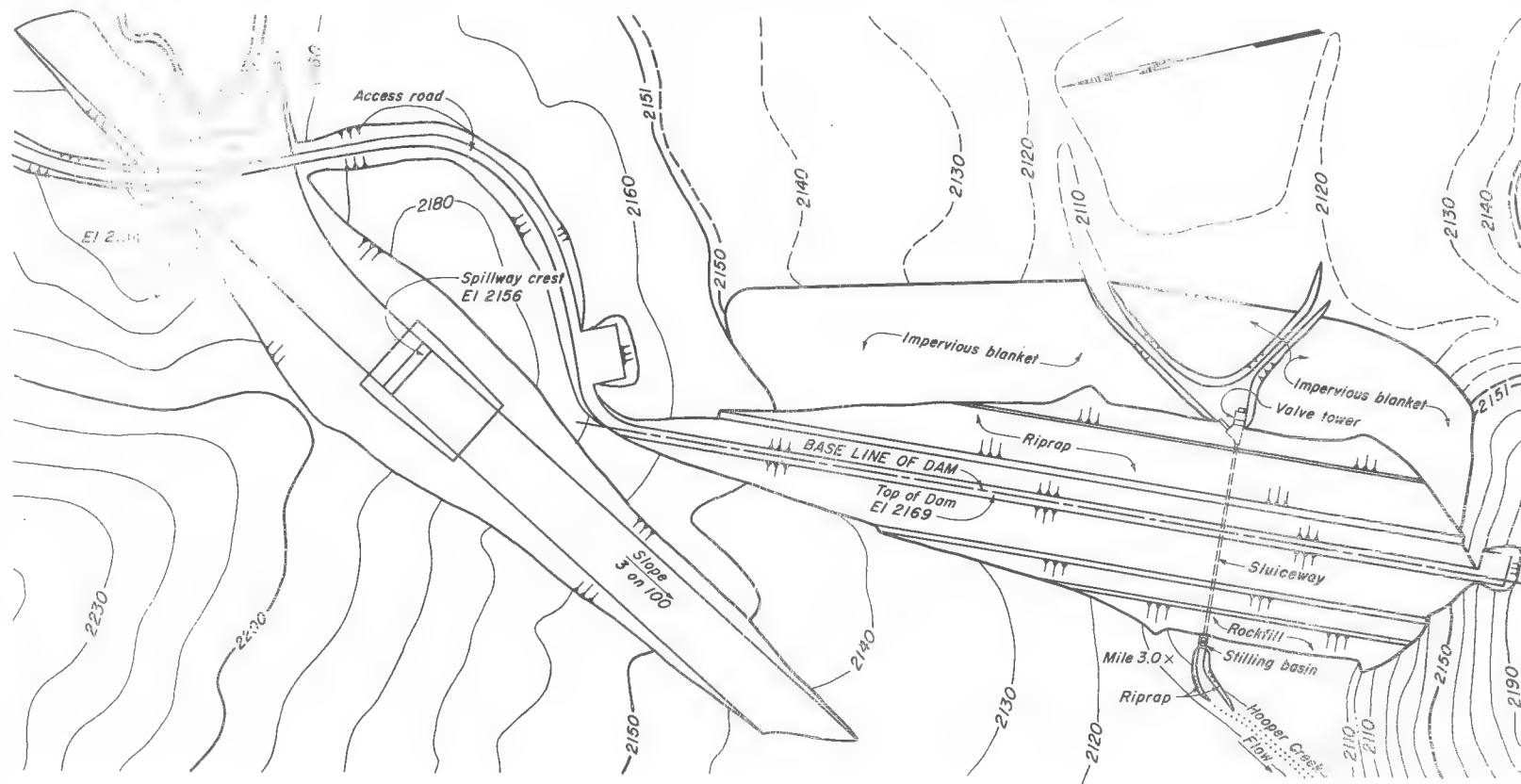
SUBMITTED	RECOMMENDED	APPROVED
<i>Jack H. Hendrix</i>	<i>Don H. Mott</i>	<i>R. G. Peltier</i>
KNOXVILLE	3-17-66 77C PP I	120 K 278RI

1	8-16-66	MTW	MGM			
REV	DATE	MADE	CHKD	SUPV	INSP	
NO.						
DRWN	MTW	COMPUTED	JLD			
TRCD		ENGINEER				
CHKD	MGM					



Figure 22 - HOOPER CREEK DAM SITE, LOOKING UPSTREAM

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1. Topography taken from Kelsh topography, 461 Q 1-401.
2. Sluiceway provided with 8 antiseep collars, 25' cc.

Scale 150 0 150 300 Feet

PLAN & ELEVATION

Scale 30 0 30 60 Feet

DAM & SPILLWAY SECTIONS

Scale 20 0 20 40 Feet

STILLING BASIN & VALVE TOWER

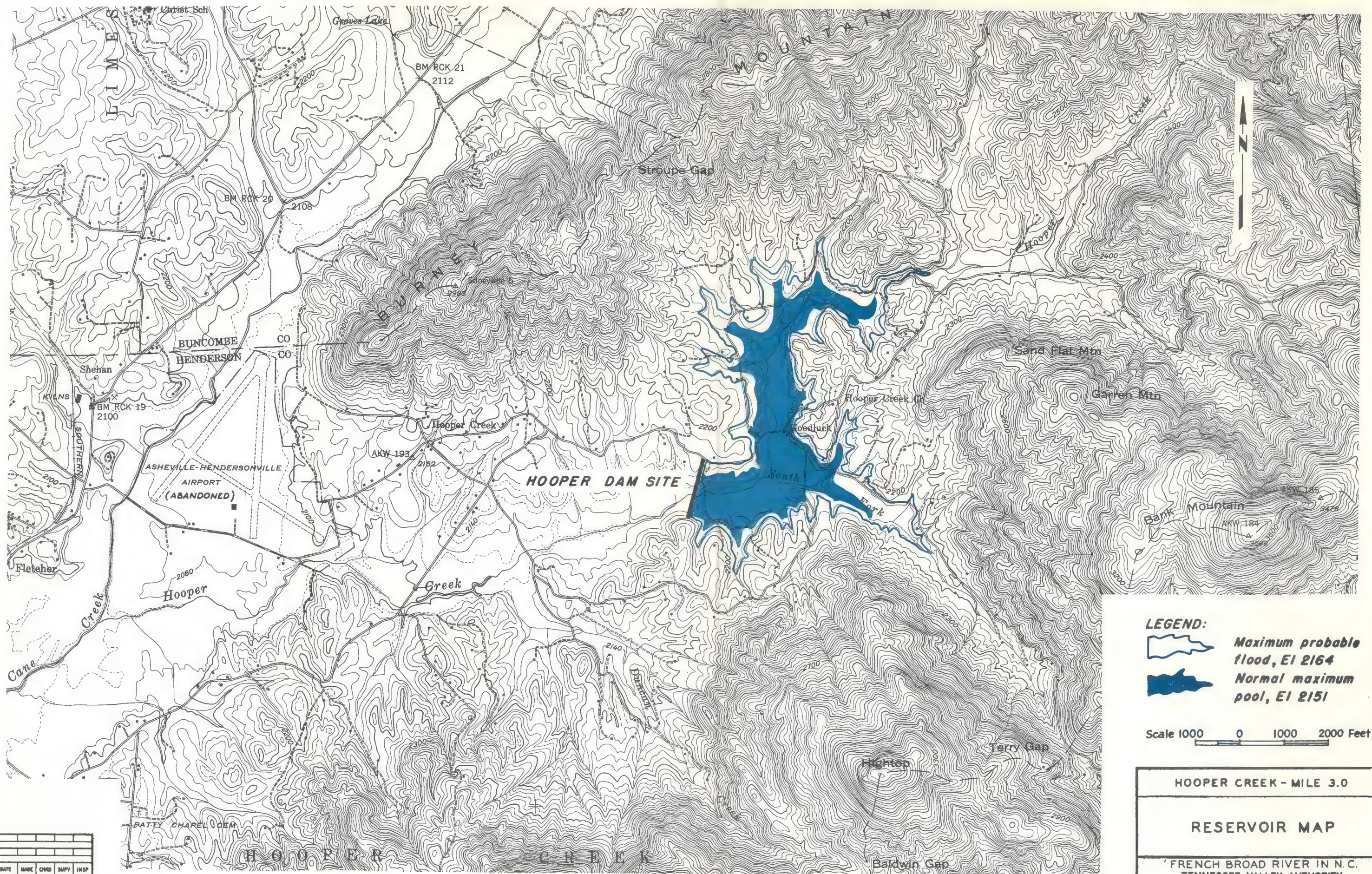
HOOPER CREEK-MILE 3.0

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack H. Hendrix	Don A. Matson	R. A. Ellis
KNOXVILLE	3-17-66 77Z PP	I 120 K 279R1

18-19-66DJC JWF									
General revision									
REV. NO.	DATE	MADE	CHKD	SUPV	INSP				
DRWN	REH	COMPUTED							
TRCD		EH, JLD							
CHKD	JWF	J. W. Bunkley							



LEGEND:

 *Maximum probable flood, EI 2164*

 *Normal maximum pool, EI 2151*

Scale 1000 0 1000 2000 Feet

HOOPER CREEK - MILE 3.0

RESERVOIR MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED <i>J. H. G. G. G.</i>	RECOMMENDED <i>Smith M. M. M.</i>	APPROVED <i>R. G. G. G.</i>
KNOXVILLE	2-1-66	77Z PP 1 453B308

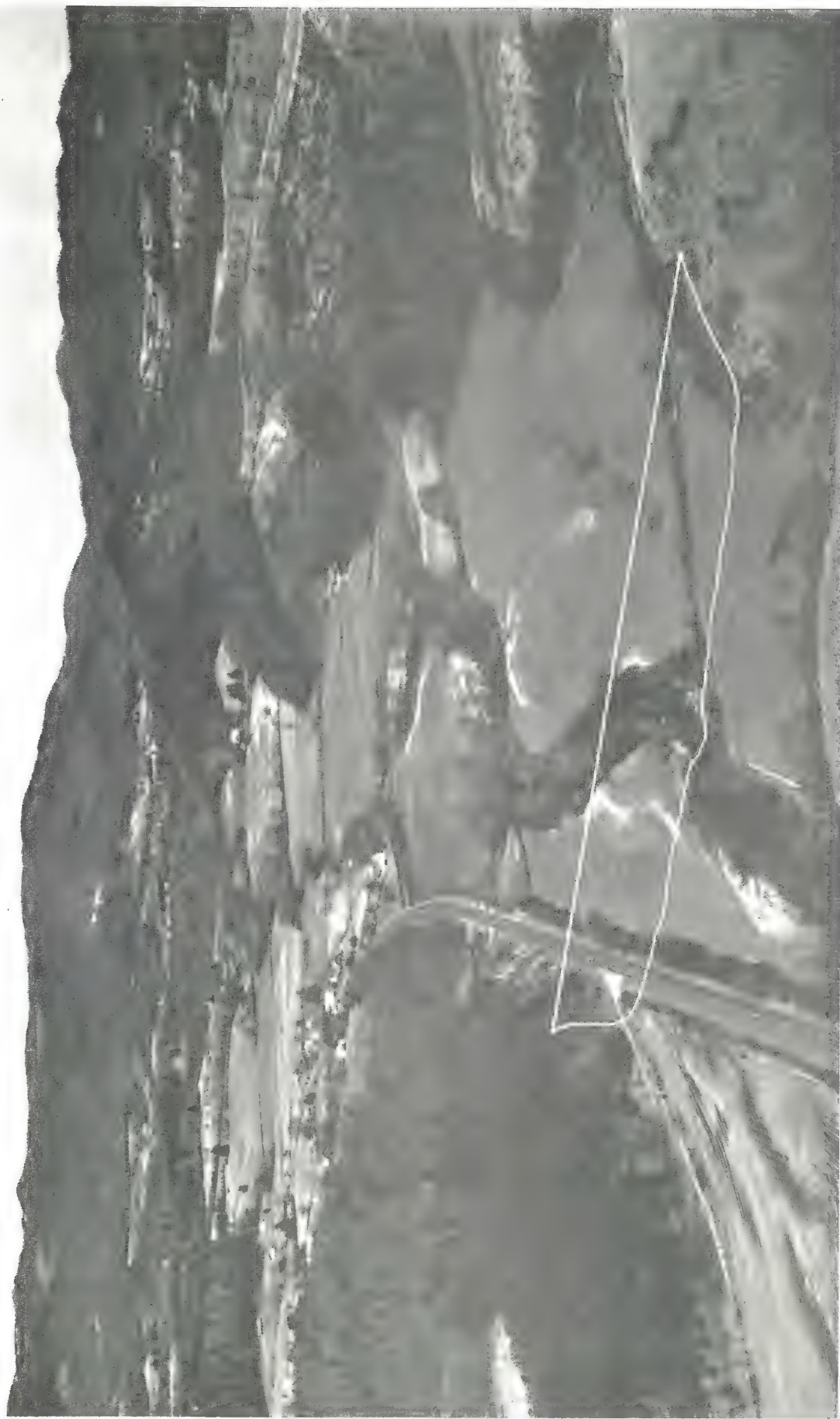
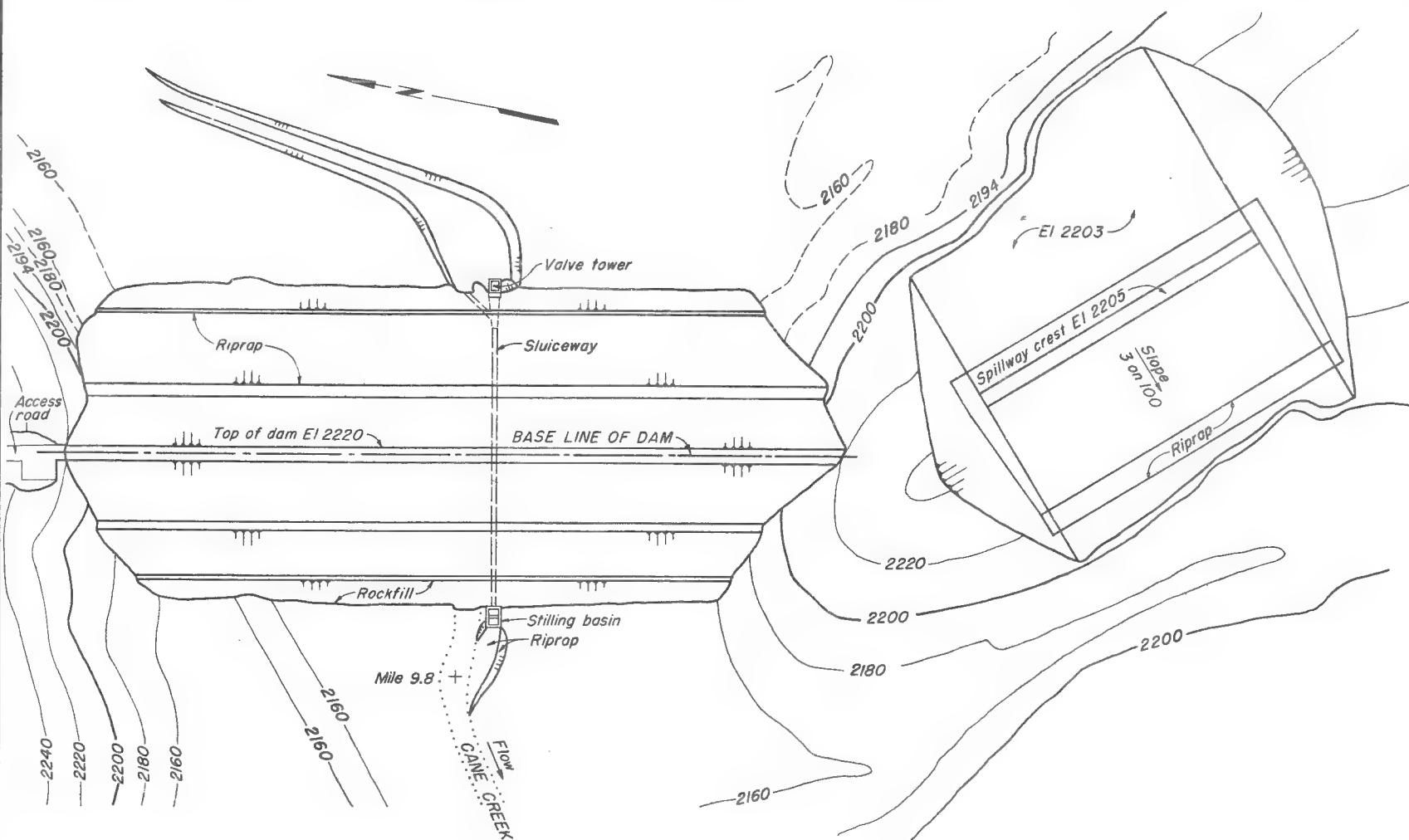
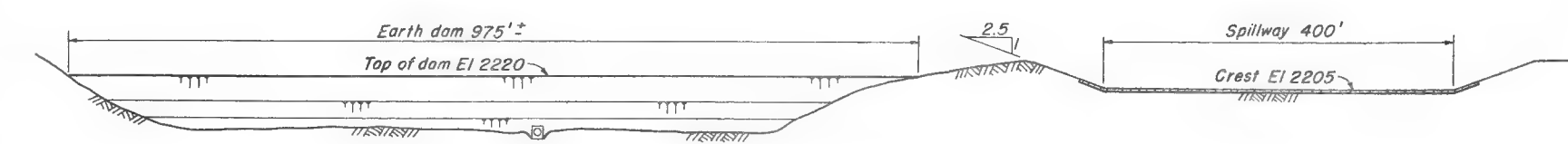


Figure 23 - CANE CREEK DAM SITE, LOOKING UPSTREAM

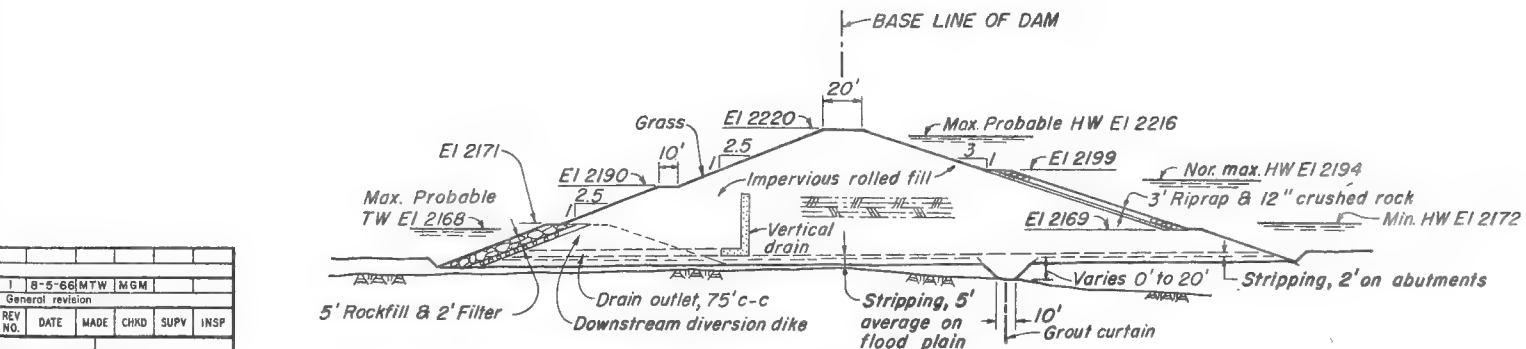
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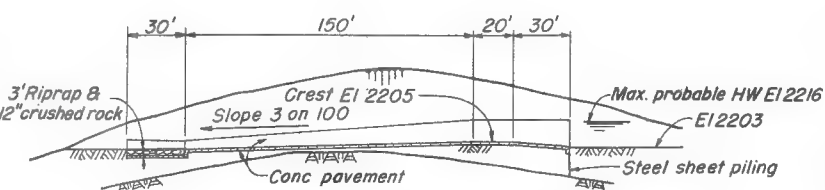
GENERAL PLAN



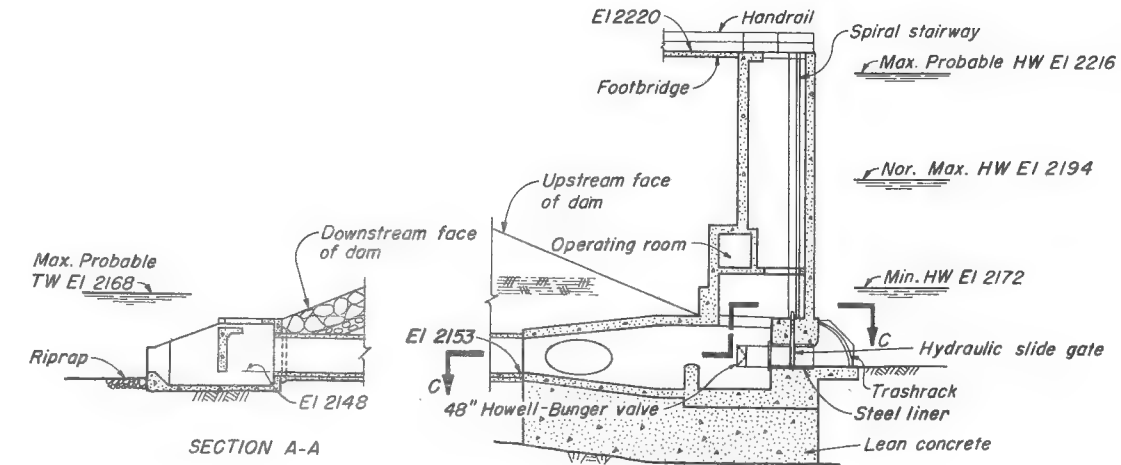
DOWNSTREAM ELEVATION



SECTION THRU DAM

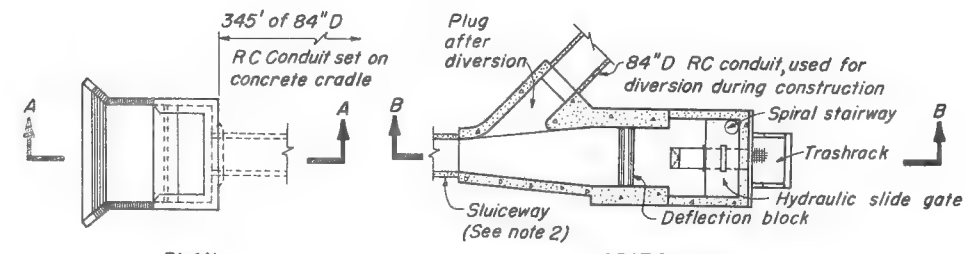


SECTION ALONG & SPILLWAY



SECTION A-A

SECTION B-B

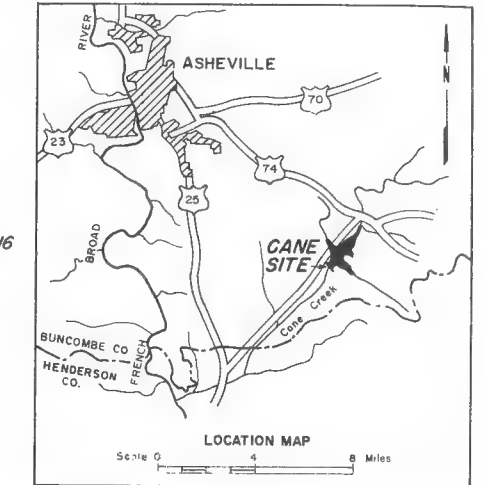


PLAN

SECTION C-C

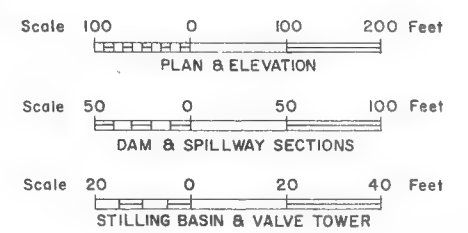
STILLING BASIN

VALVE TOWER



LOCATION MAP

- NOTES:
1. Topography taken from Kelsh topography, 461 P 691-4.
 2. Sluiceway provided with 8 antiseep collars 25 cc.



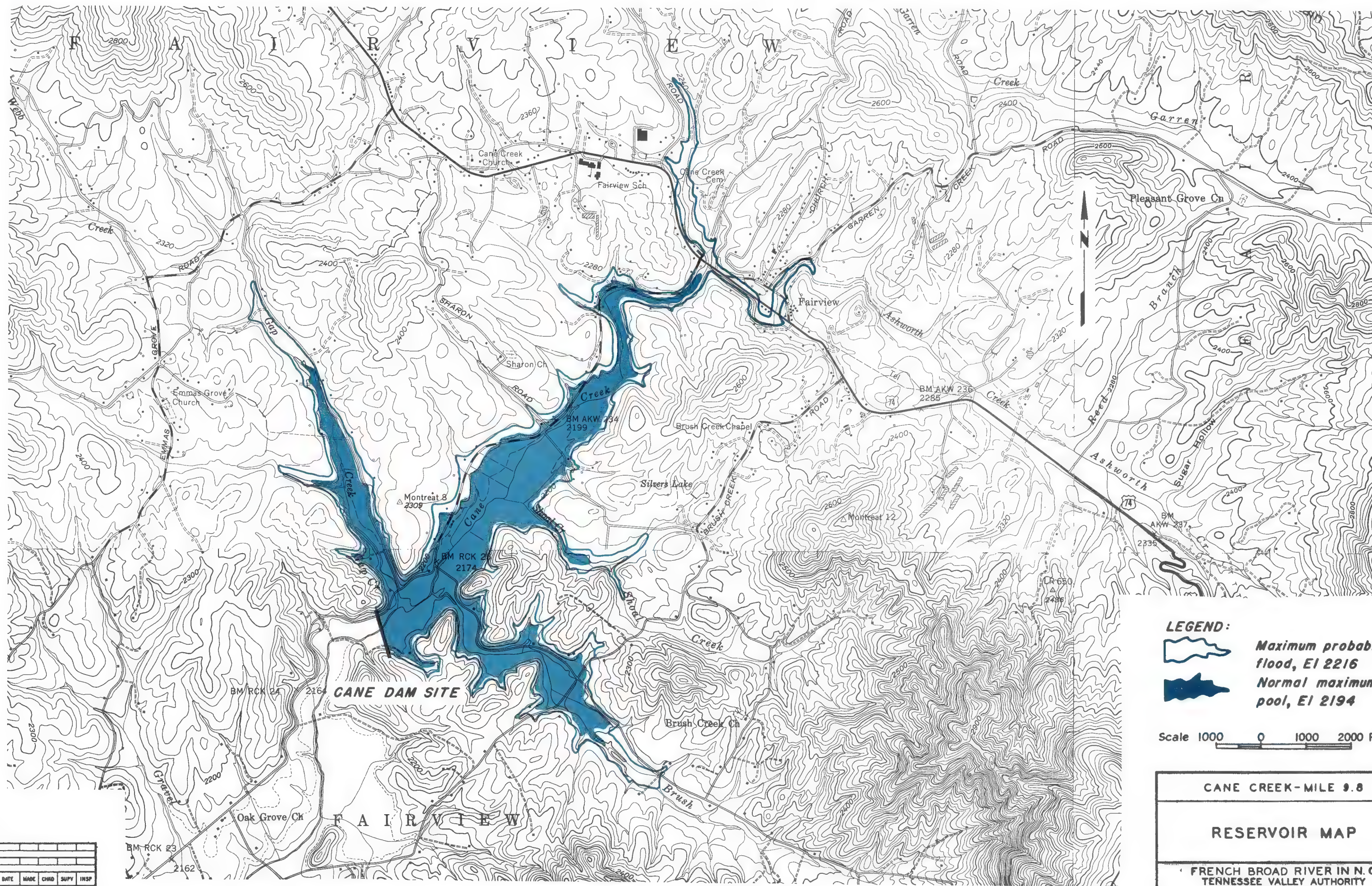
CANE CREEK-MILE 9.8

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack H. Hendrix	Don H. Mattson	Paul E. Leland
KNOXVILLE	3-17-66 77J PP 1	120 K 280R1

1	8-5-66	MTW	MGM			
REV	NO.	DATE	MADE	CHKD	SUPV	INSP
DRWN	DJC	COMPUTED				
TRCD		ENGINEER				
CHKD	MGM	Maurice E. Hendrix				



LEGEND:

 Maximum probable flood, El 2216

 Normal maximum pool, El 2194

Scale 1000 0 1000 2000 Feet

CANE CREEK - MILE 9.8

RESERVOIR MAP

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED <i>[Signature]</i>	RECOMMENDED <i>[Signature]</i>	APPROVED <i>[Signature]</i>
KNOXVILLE	2-1-66 77J PP 1	453B309

REV NO.	DATE	MADE	CHD	SUP	INSP
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

BY: *[Signature]* COMPUTED: *[Signature]*

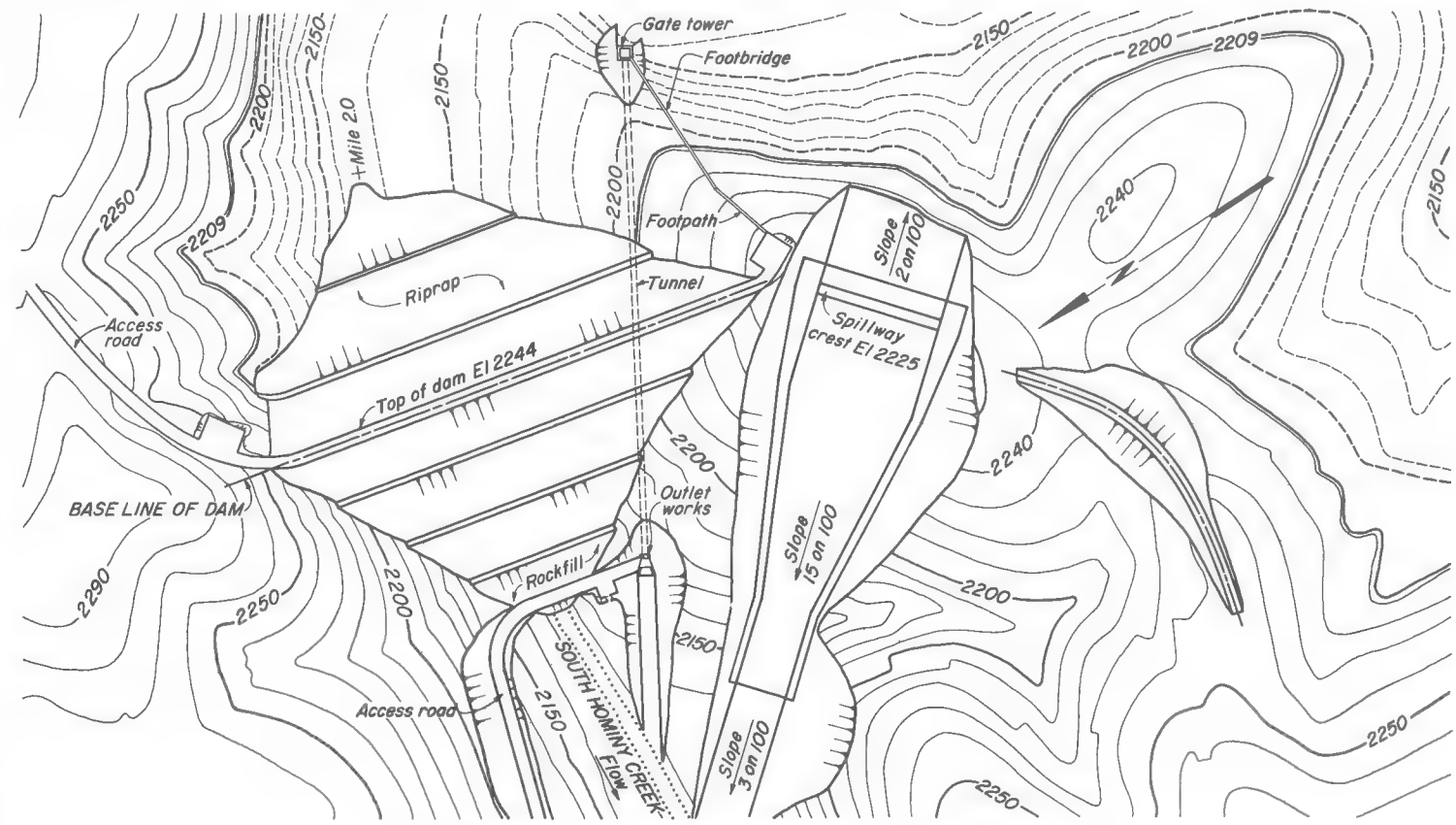
TRD: *[Signature]* ENGINEER: *[Signature]*

CHK: *[Signature]*

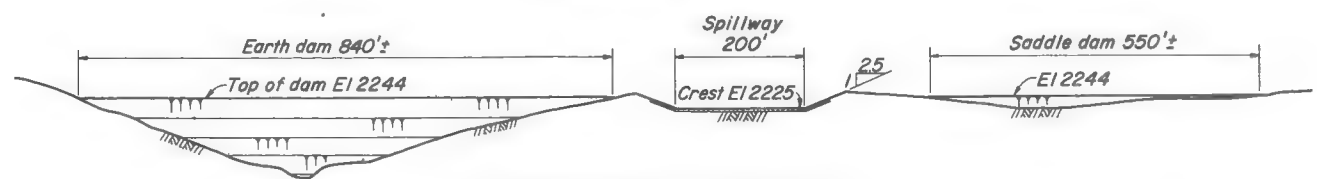


Figure 24 - SOUTH HOMINY CREEK DAM SITE, LOOKING UPSTREAM

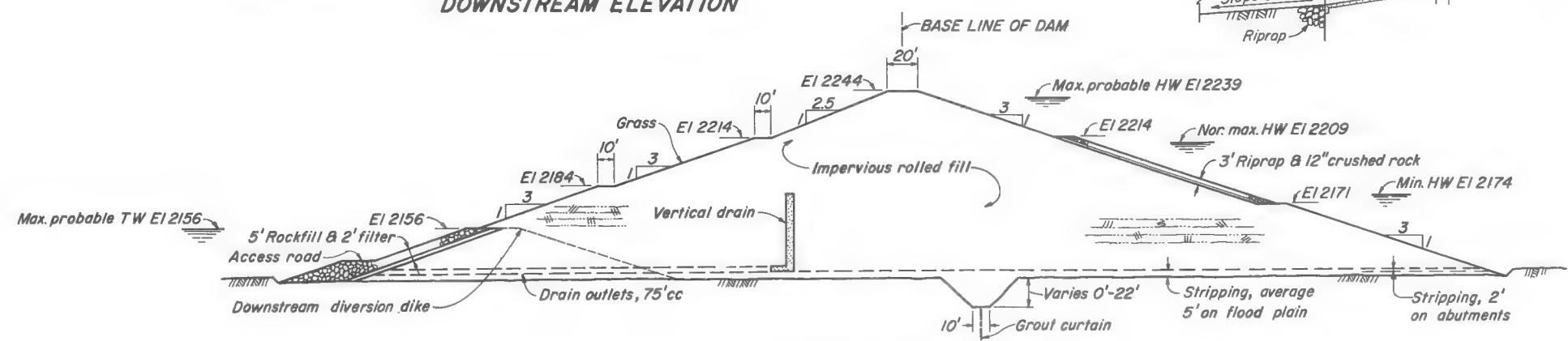
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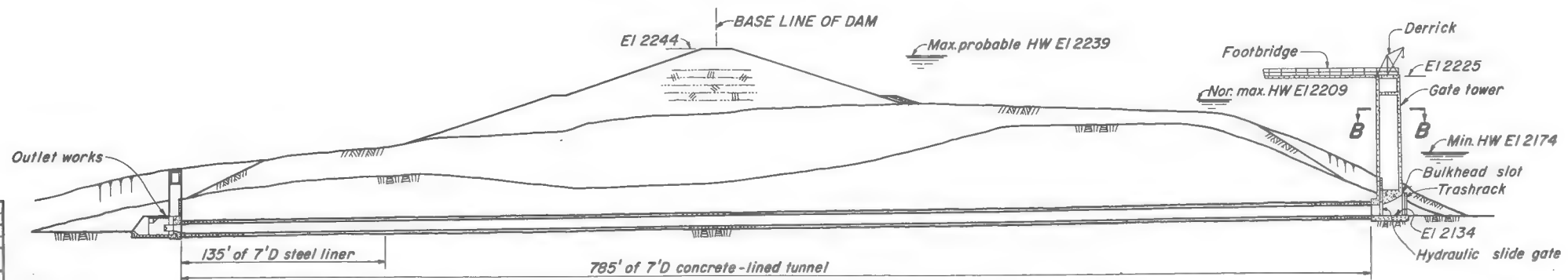
GENERAL PLAN



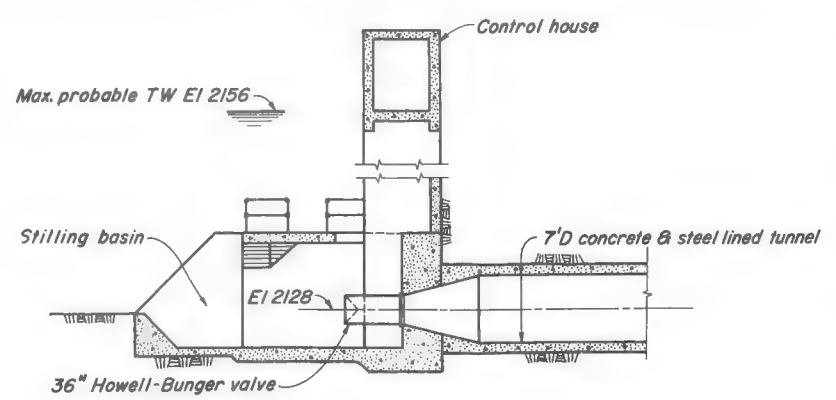
DOWNSTREAM ELEVATION



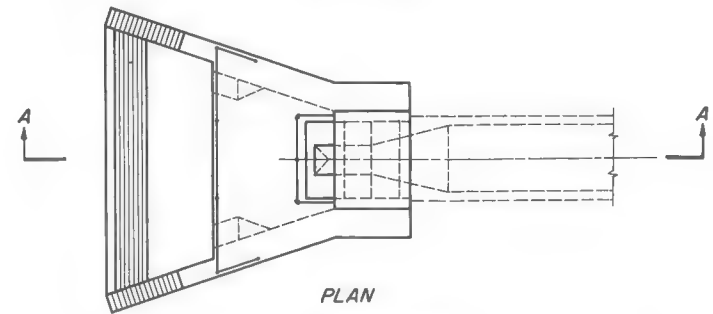
SECTION THRU DAM



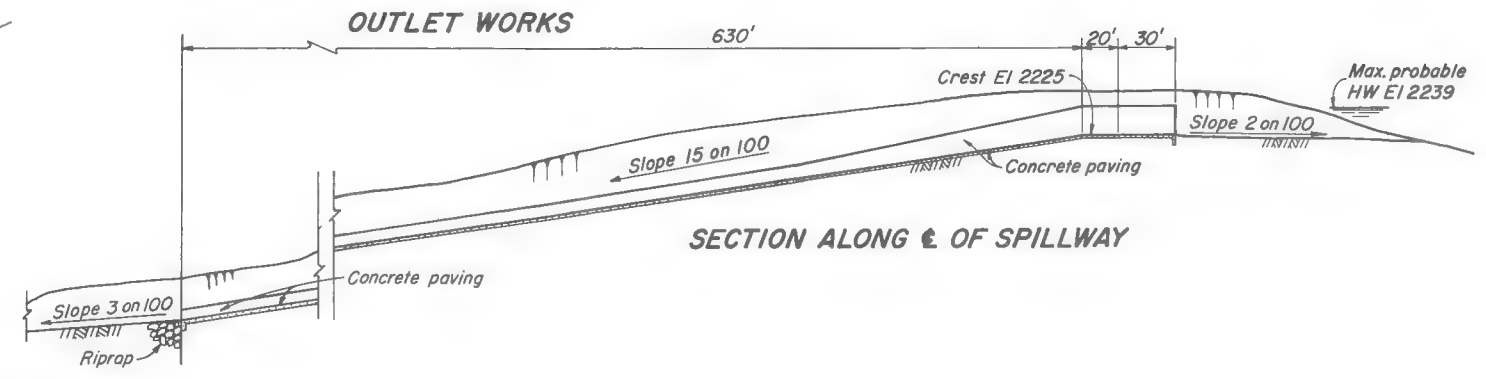
SECTION ALONG C OF OUTLET TUNNEL



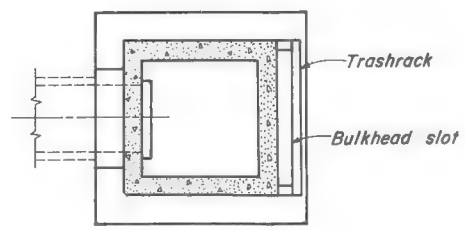
SECTION A-A



PLAN

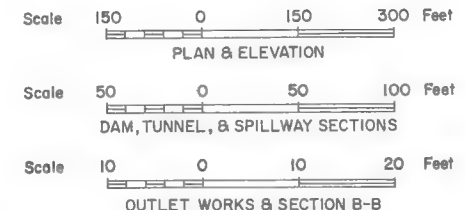


SECTION ALONG E OF SPILLWAY



SECTION B-B

NOTE:
Topography taken from Kelsh topography,
461P691-2R2.



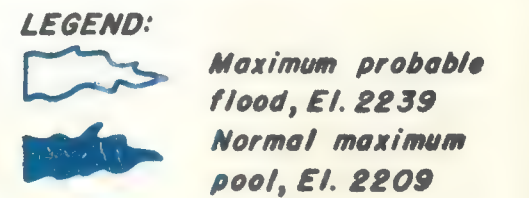
SOUTH HOMINY CREEK-MILE 2.0

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
<i>Jack E. H. H. H.</i>	<i>Don H. Mattison</i>	<i>R. L. H. H.</i>
KNOXVILLE	3-17-66 77E PP 1	120 K 281R1

REV	NO.	DATE	MADE	CHKD	SUPV	INSP
1	8-19-66	MTW	JWF			
General revision						
DRWN	EH	COMPUTED	JBP, LWC			
TRCD	JWB	ENGINEER				
CHKD	JWB					



SOUTH HOMINY CREEK - MILE 2.0

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

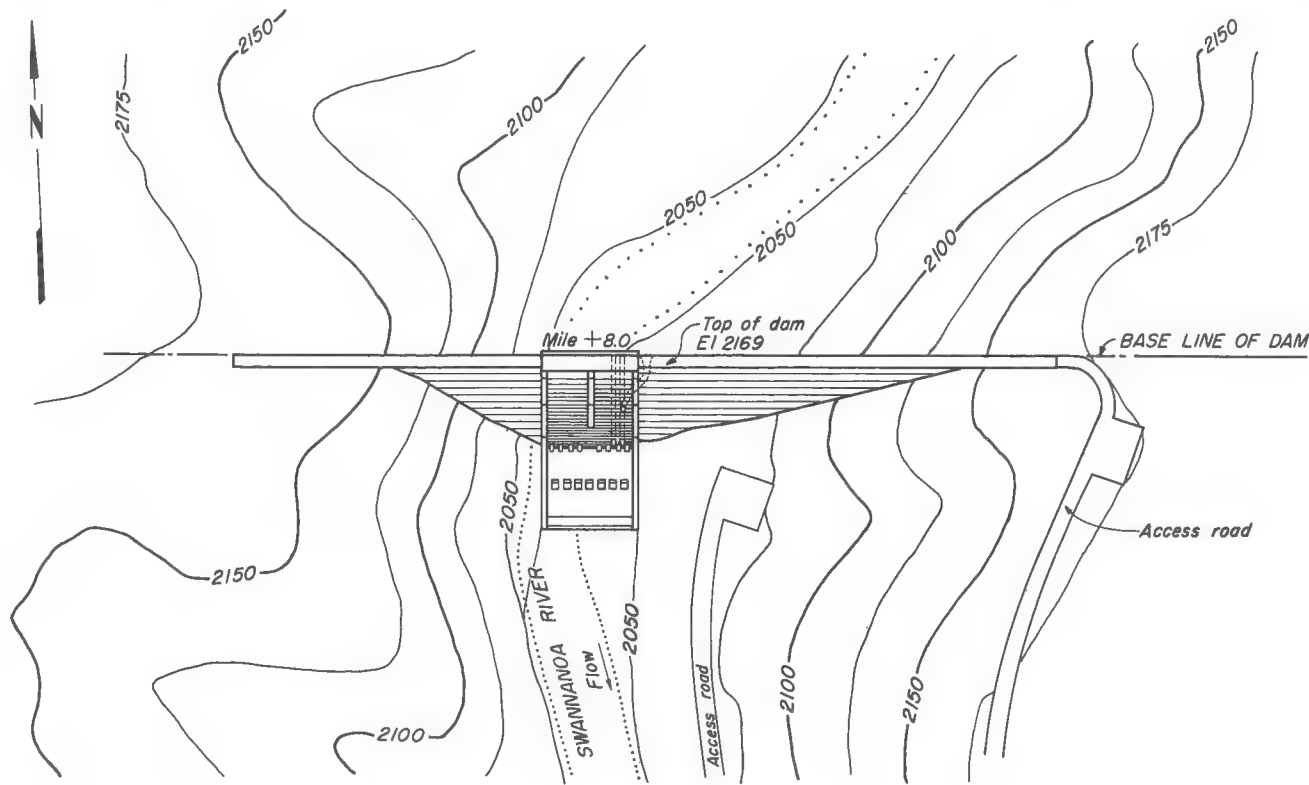
SUBMITTED <i>J. H. Hendrix</i>		RECOMMENDED <i>Don H. Matten</i>		APPROVED <i>P. G. Ellis</i>	
KNOXVILLE		2-1-66	77E	PP	4538310

REV NO.	DATE	MADE	CHNG	SUPP	INSP
DRAWN _____					
TWO _____					
CHNG _____	COMPUTED _____ ENGINEER <i>J.W. Binkley</i>				

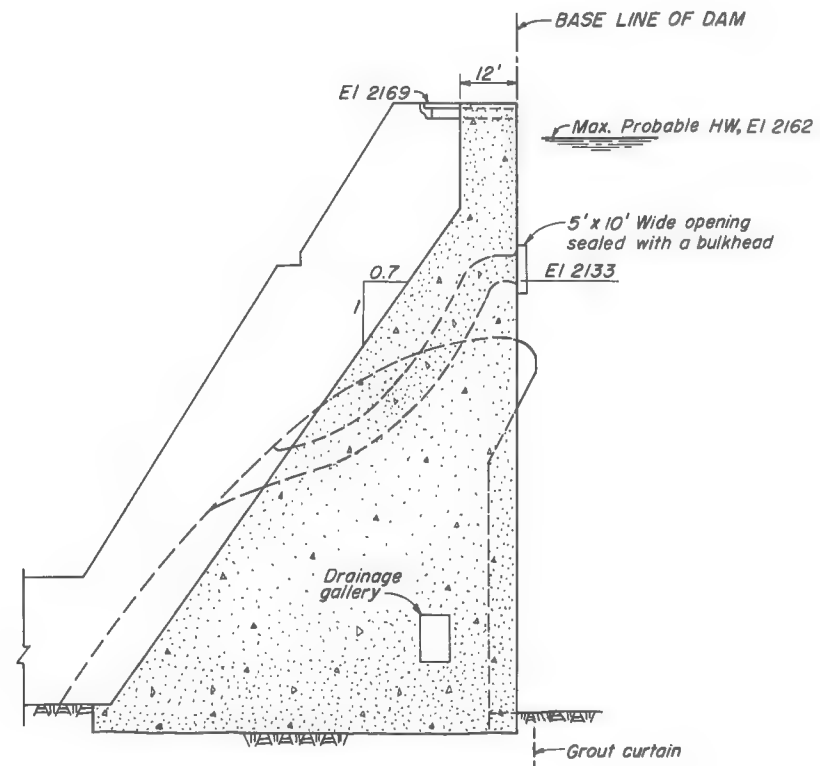


Figure 25 - SWANNANOA RIVER DAM SITE, LOOKING UPSTREAM

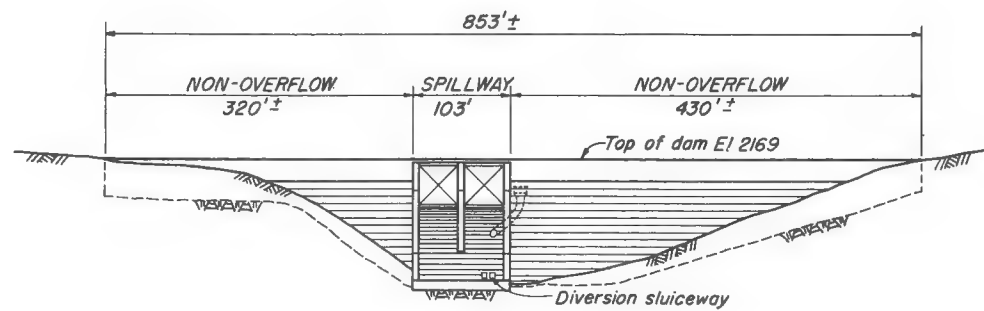
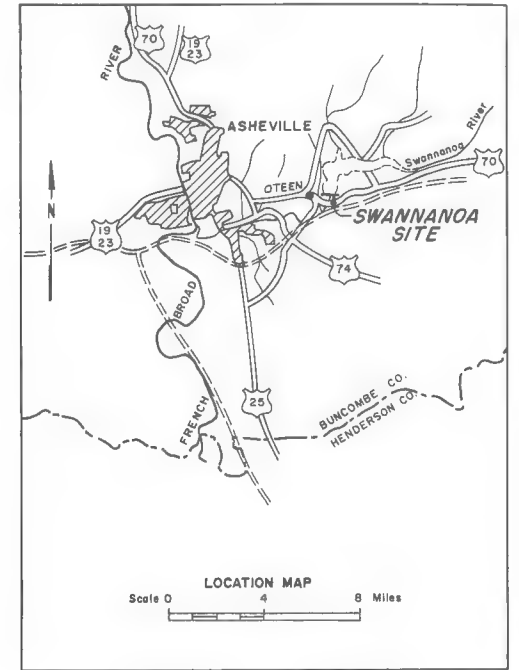
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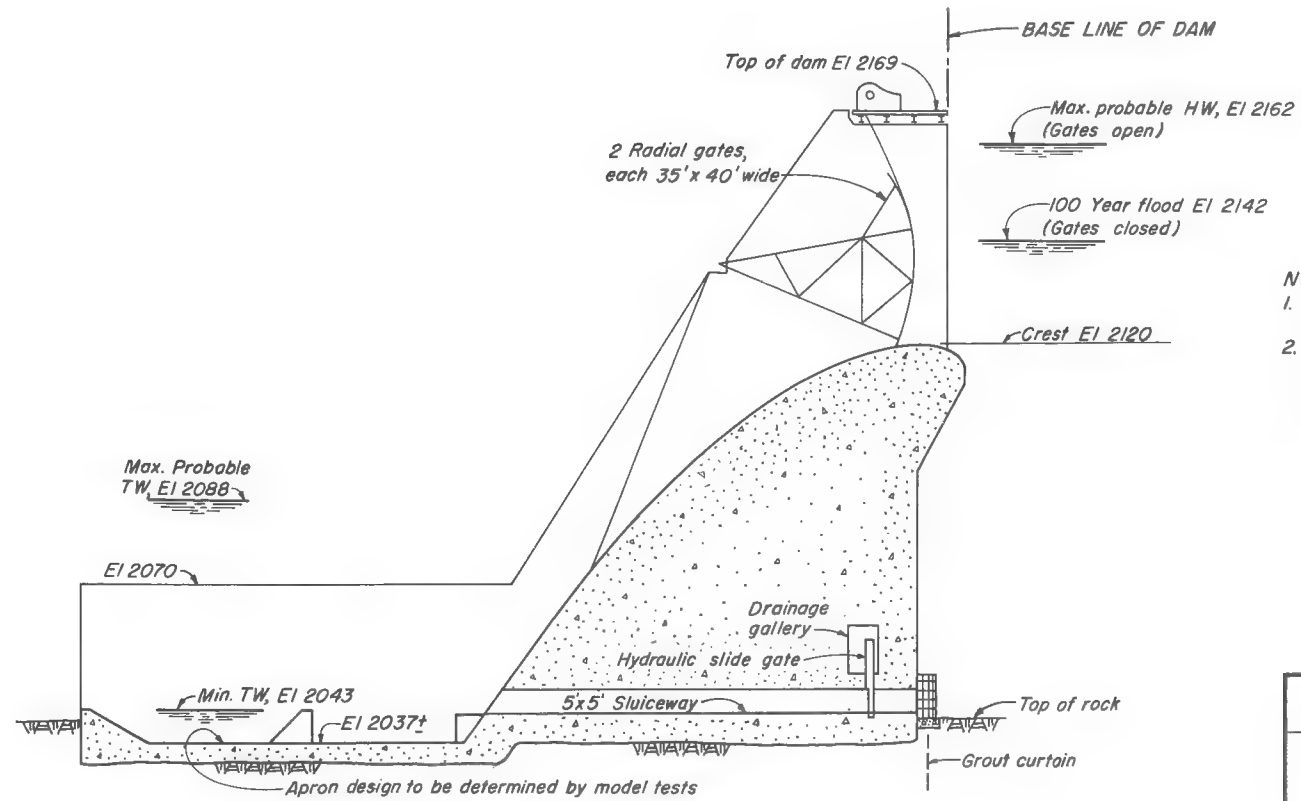
GENERAL PLAN



NON-OVERFLOW SECTION



DOWNSTREAM ELEVATION



SPILLWAY SECTION

- NOTES:
1. Topography taken from Kelsh topography, 462 Q 556-231.
 2. Provisions have been made for a possible future permanent pool at Elevation 2133 with closure expected 5 years after completion of dam.



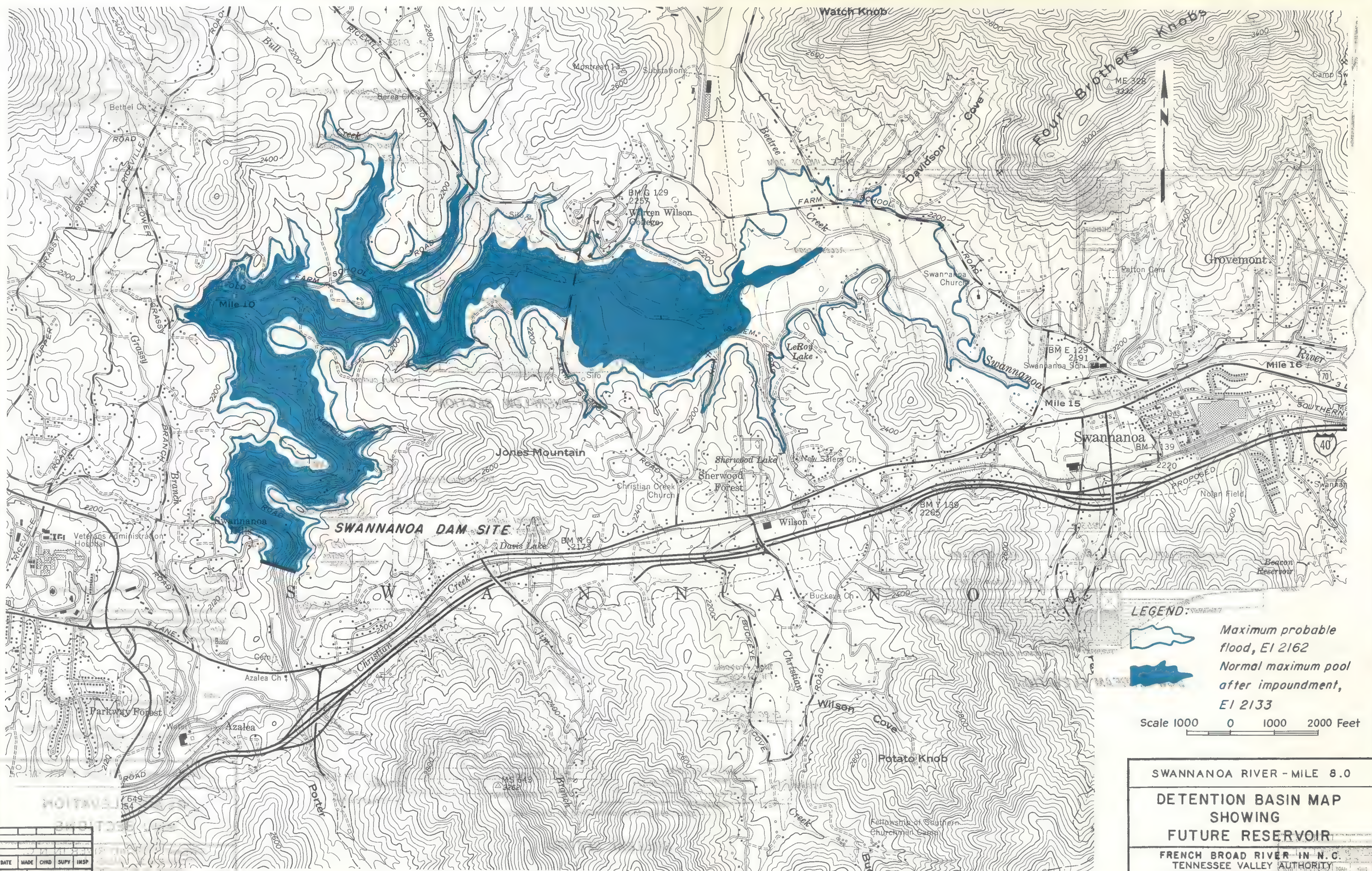
SWANNANOA RIVER-MILE 8.0

PLAN, ELEVATION
AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack H. Hendrix	Don H. Mattern	R. L. Egan
KNOXVILLE	3-17-66 770 PP	I 120 K 282R1

1	8-17-66	MTW	JWF			
REV	DATE	MADE	CHD	SUPV	INSP	
NO.						
DRWN	JJC	COMPUTED	JWB & TSF			
TRCD		ENGINEER				
CHKD	JWF	J. W. Binkley				



LEGEND:



Maximum probable
flood, EI 2162



Normal maximum pool
after impoundment,
EI 2133

Scale 1000 0 1000 2000 Feet

SWANNANOA RIVER - MILE 8.0

**DETENTION BASIN MAP
SHOWING
FUTURE RESERVOIR**

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED: *J.H. Hendrix* RECOMMENDED: *Don H. Matheson* APPROVED: *R.C. Elliott*

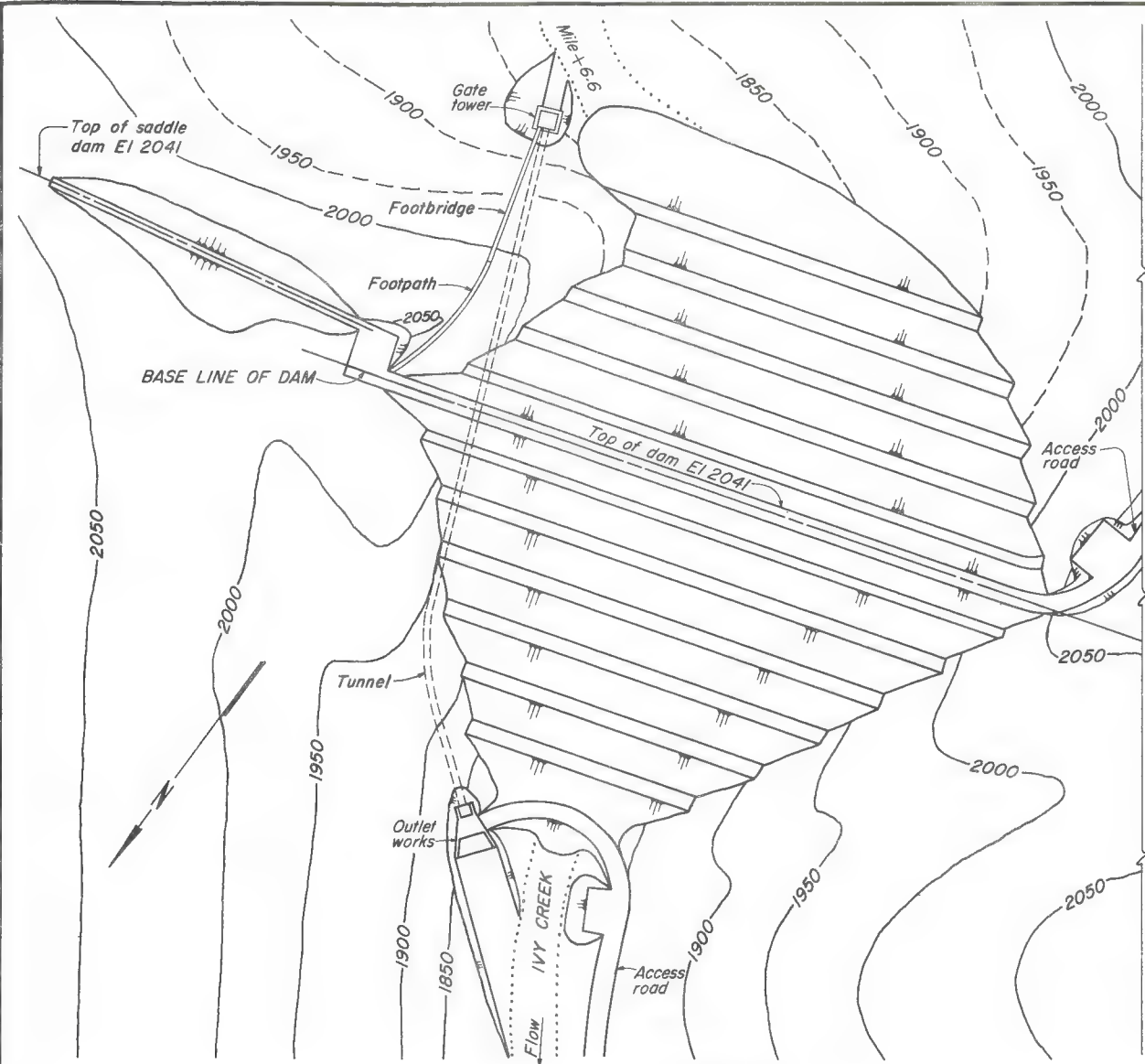
KNOXVILLE 2-1-66 77D RP 453B311

REV NO.	DATE	MADE	CHD	SUPP	INSP
BWVN		COMPUTED			
TDCD		ENGINEER			
CHD		<i>J.W. Runkley</i>			

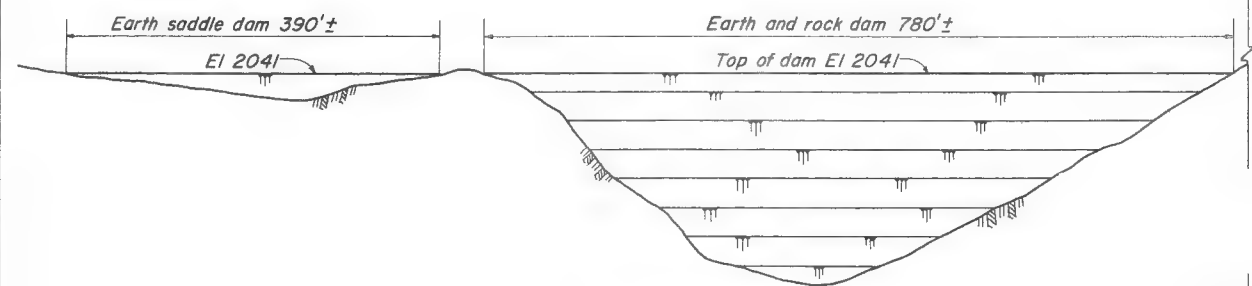


Figure 26 - IVY CREEK DAM SITE, LOOKING UPSTREAM

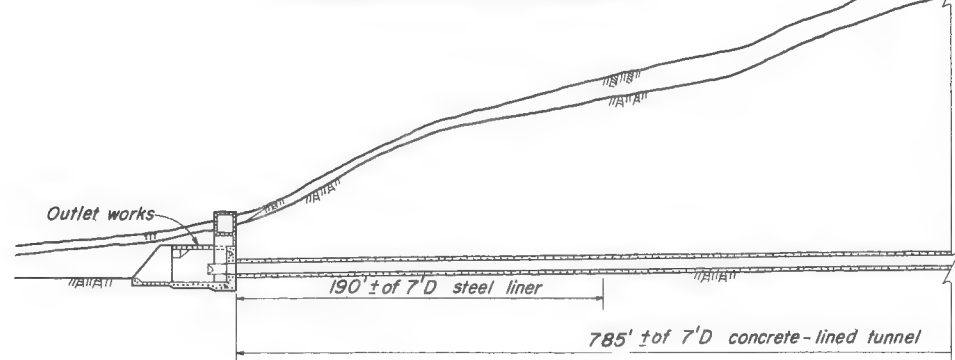
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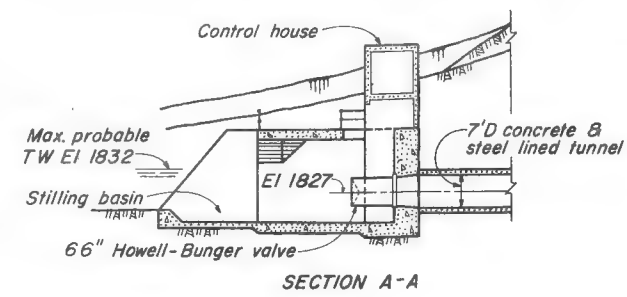
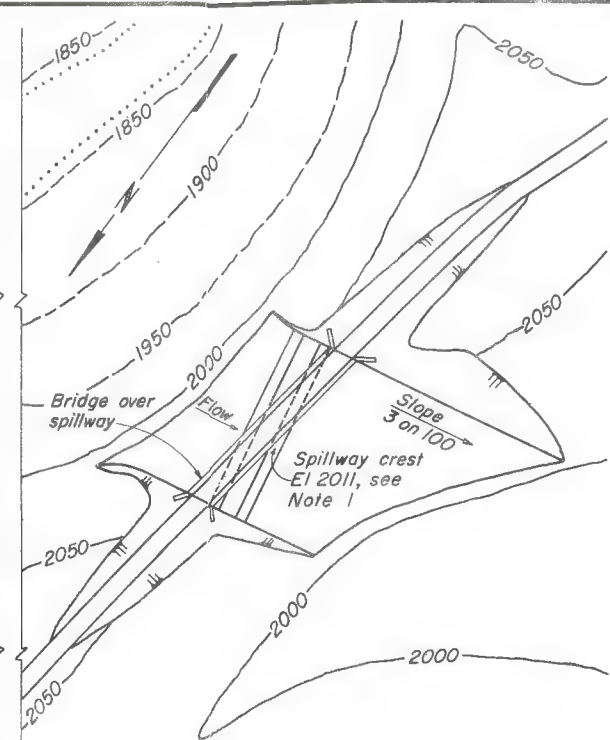
GENERAL PLAN



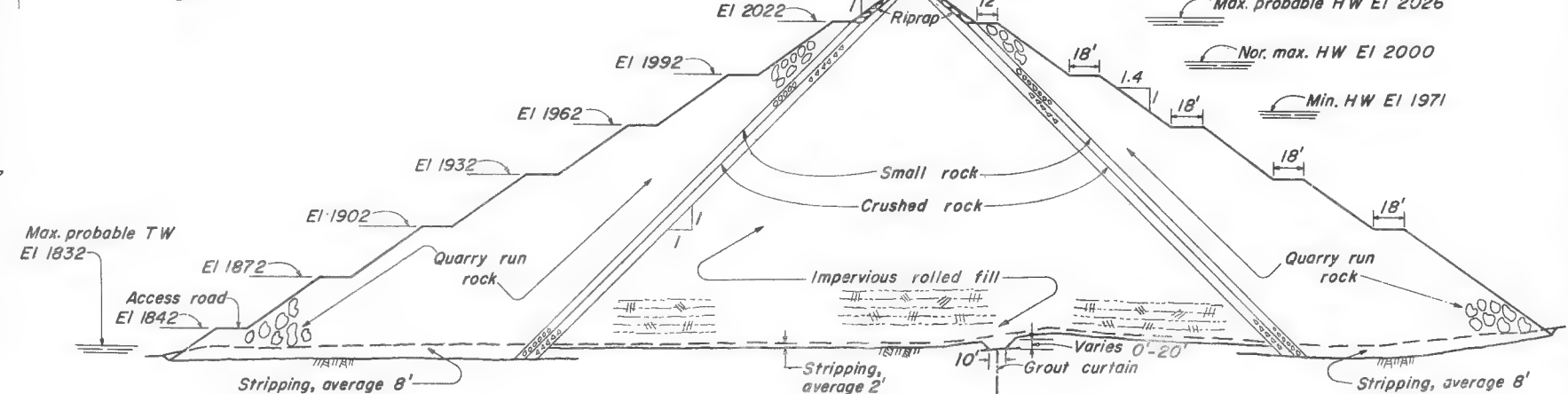
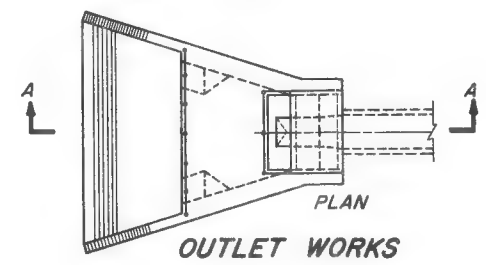
DOWNSTREAM ELEVATION



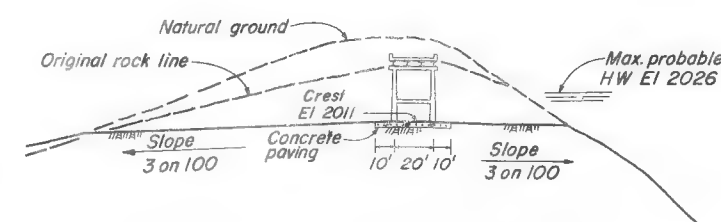
SECTION ALONG & OF OUTLET TUNNEL



SECTION A-A

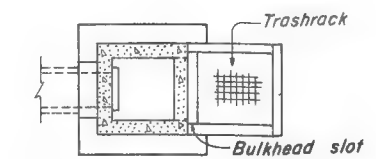
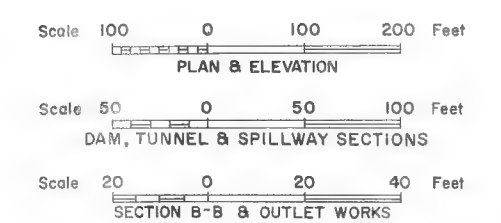


SECTION THRU DAM



SECTION ALONG & OF SPILLWAY

NOTES:
1. Location of spillway in relation to dam shown on 461 K 121.
2. Topography taken from Kelsh topography, 461 Q 742 - 402 R1.



SECTION B-B

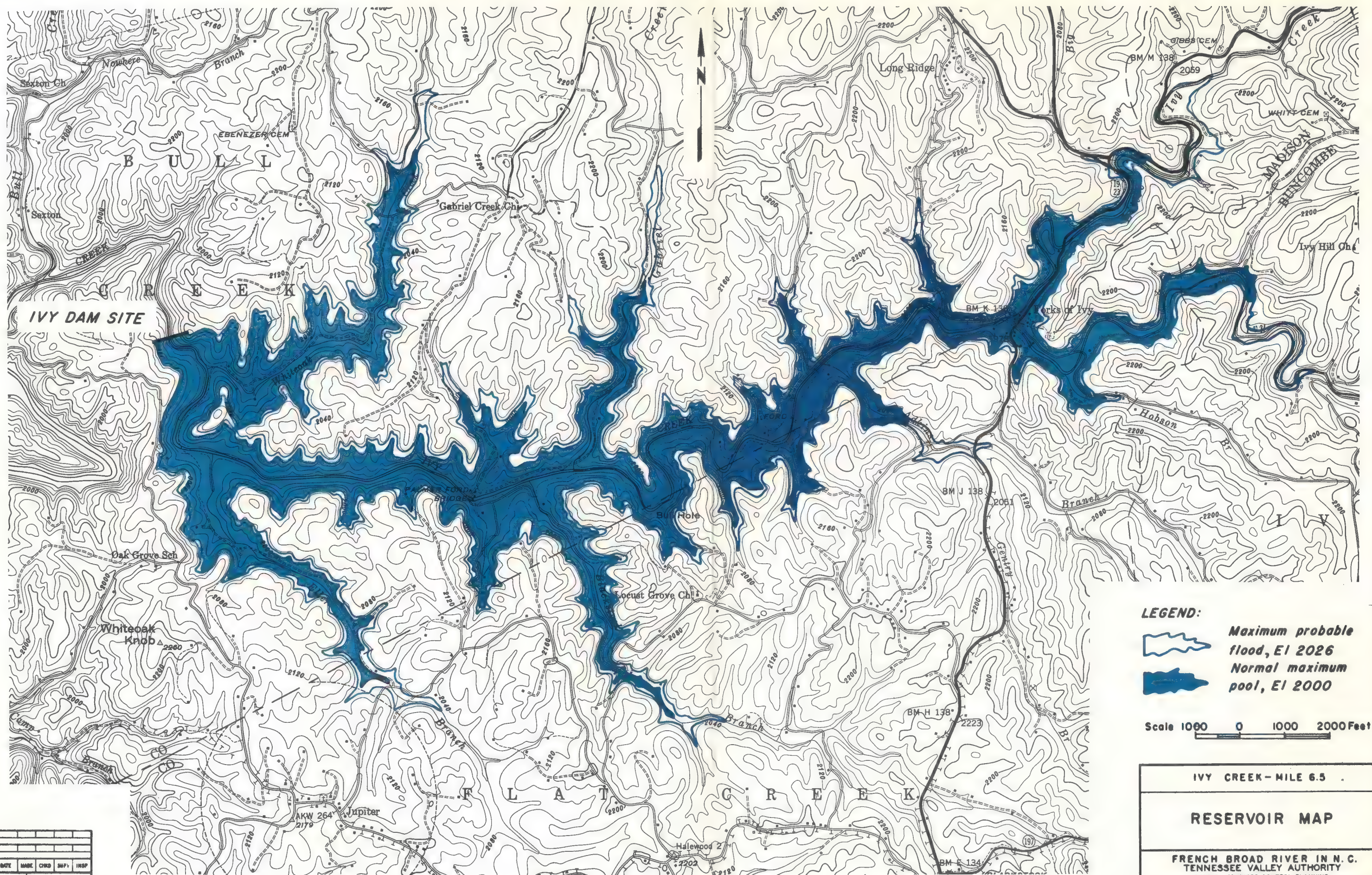
IVY CREEK - MILE 6.5

PLAN, ELEVATION AND SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Jack B. Hendrix	Don H. Mattson	R. L. Ewing
KNOXVILLE	3-17-66 77A PP 1	120 K 283R1

REV	NO.	DATE	MADE	CHKD	SUPV	INSP
1	8-10-66	MTW	JWF			
General revisions						
DRWN	MTW	COMPUTED	LWC & TSG			
TRCD	JWF	ENGINEER	J. W. Binsley			
CHKD	JWF					



LEGEND:

**Maximum probable
flood, EI 2026
Normal maximum
pool, EI 2000**

Scale 1000 0 1000 2000 Feet

IVY CREEK - MILE 6.5

RESERVOIR MAP

FRENCH BROAD RIVER IN N. C.
TENNESSEE VALLEY AUTHORITY

SUBMITTED	RECOMMENDED	APPROVED
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KNOXVILLE		3-23-66	77A	PP	1	4538312
-----------	--	---------	-----	----	---	---------

REV	DATE	MADE	CHG	SHP	INSP
NO.					
DRAWN			COMPUTED		
TRCD			ENGINEER		
CHG			J. H. B. B. B.		

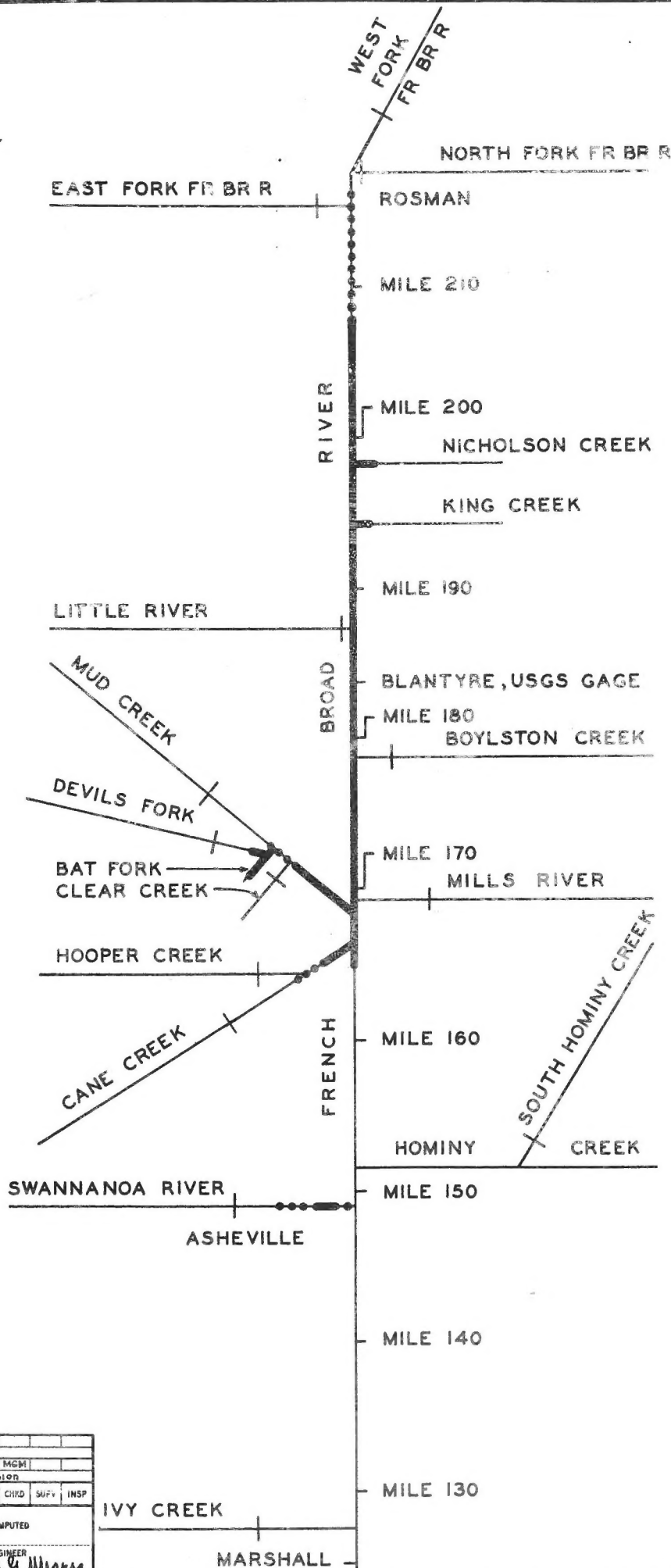


Figure 27 - AREA OF PROPOSED CHANNEL IMPROVEMENTS ON FRENCH BROAD RIVER NEAR KINGS BRIDGE.



Figure 28 - FRENCH BROAD RIVER AT ASHEVILLE, LOOKING UPSTREAM, SHOWING ALIGNMENT OF PROPOSED LEVEE.

CHANNEL CAPACITIES AND 5-YEAR CROP SEASON FLOWS



Location		Capacity, CFS		5-Yr Crop Season Flow, CFS	
Reference	Stream Mile	Existing Channel	Improved Channel	Natural	Regulated
<u>French Broad River</u>					
Jct. North and West Forks	217.7	2,340	-	5,800	1,800
At East Fork	215.5	2,240	2,300	6,100	2,300
Former gage at Calvert	214.0	1,200	2,500	7,000	2,500
0.4 Mile below Cathys Creek	207.8	3,280	3,600	7,600	3,600
0.4 Mile above U.S. 276 bridge	196.9	2,200	4,400	8,300	4,400
0.6 Mile below Davidson River	191.1	4,330	5,700	9,500	5,700
At Little River	187.2	2,340	5,900	9,700	5,900
0.3 Mile above Little Willow Creek	181.2	4,020	6,800	11,100	6,800
0.5 Mile above Big Willow Creek	180.3	2,045	6,900	11,200	6,900
0.3 Mile below Johnson Bridge	173.0	3,865	7,600	11,600	7,600
At Boylston Creek	170.8	3,000	8,200	11,950	8,200
0.2 Mile above Mud Creek	168.7	2,385	9,200	13,100	9,200
0.2 Mile above Cane Creek	167.1	3,150	9,700	14,600	9,700
0.6 Mile above Fanning Bridge	166.0	6,500	10,000	15,800	10,000
0.3 Mile above Glenn Bridge	163.2	13,120	-	16,100	10,300
0.3 Mile below Bent Creek gage	157.4	14,650	-	16,300	10,500
0.1 Mile above Hominy Creek	151.6	5,720	-	16,500	10,700
At Swannanoa River	149.0	10,750	-	17,500	11,200
<u>Nicholson Creek</u>					
0.5 Mile above mouth	0.5	430	600	600	600
<u>King Creek</u>					
0.5 Mile below U.S. 64 bridge	0.8	450	550	550	550
<u>Boylston Creek</u>					
0.4 Mile above mouth	0.4	340	-	580	245
<u>Mills River</u>					
0.9 Mile above mouth	0.9	3,000	-	3,500	1,150
<u>Mud Creek</u>					
0.4 Mile above mouth	0.4	1,400	2,650	5,100	2,650
0.2 Mile below Clear Creek	5.4	1,900	2,050	4,000	2,050
0.2 Mile below Bat Fork	6.6	1,300	1,710	2,380	1,710
0.1 Mile above Shephard Creek	10.0	800	800	950	560
<u>Bat Fork</u>					
0.7 Mile below U.S. 64 bridge	0.2	700	1,280	1,375	1,280
<u>Devils Fork</u>					
0.5 Mile above U.S. 64 bridge	0.6	400	600	700	600
<u>Cane Creek</u>					
0.6 Mile above mouth	0.6	1,100	1,550	2,850	1,550
0.5 Mile above Hooper Creek	3.8	750	1,150	2,250	1,150
At county line	4.7	1,400	-	2,250	1,050
<u>Hooper Creek</u>					
1.3 Miles above mouth	1.3	1,400	-	1,000	600
<u>Hominy Creek</u>					
0.3 Mile above mouth	0.3	4,200	-	4,050	3,000
<u>Swannanoa River</u>					
At mouth	0	5,500	5,550	5,600	2,000
<u>Ivy Creek</u>					
1.9 Mile above mouth	1.9	1,700	-	5,500	2,000

LEGEND

- Dam site
- Channel excavation
- Channel clearing

Scale 5 0 5 10 Miles

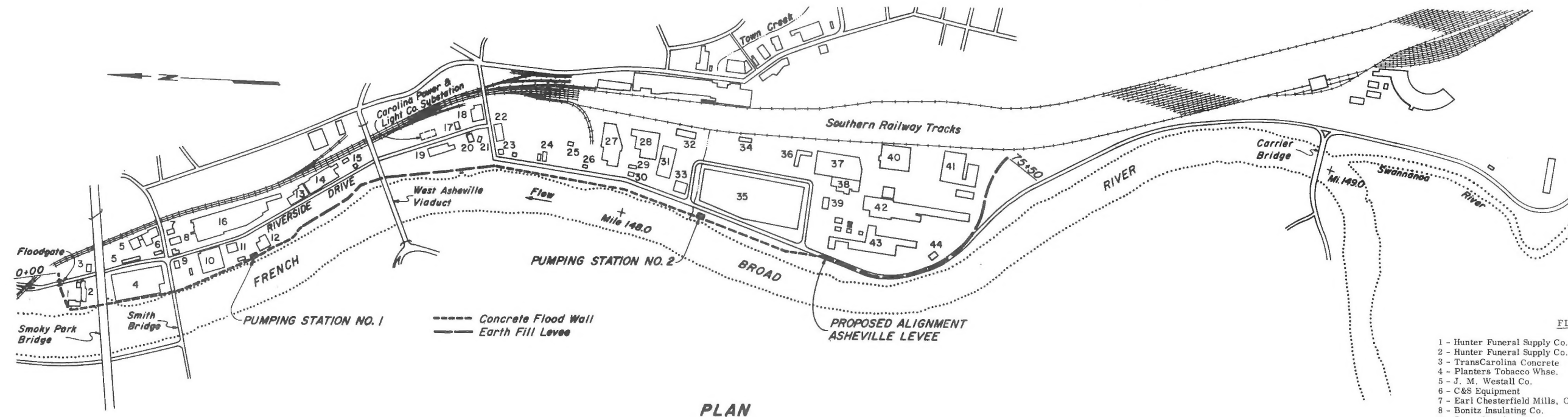
REV NO.	DATE	MADE	CHD	SUPV	INSP
1	8-30-66	REM	MGM		
General revision					
DRWN	COMPUTED				
TRCD	ENGINEER				
CHKD	M. G. Nicksa				

FRENCH BROAD RIVER & TRIBUTARIES

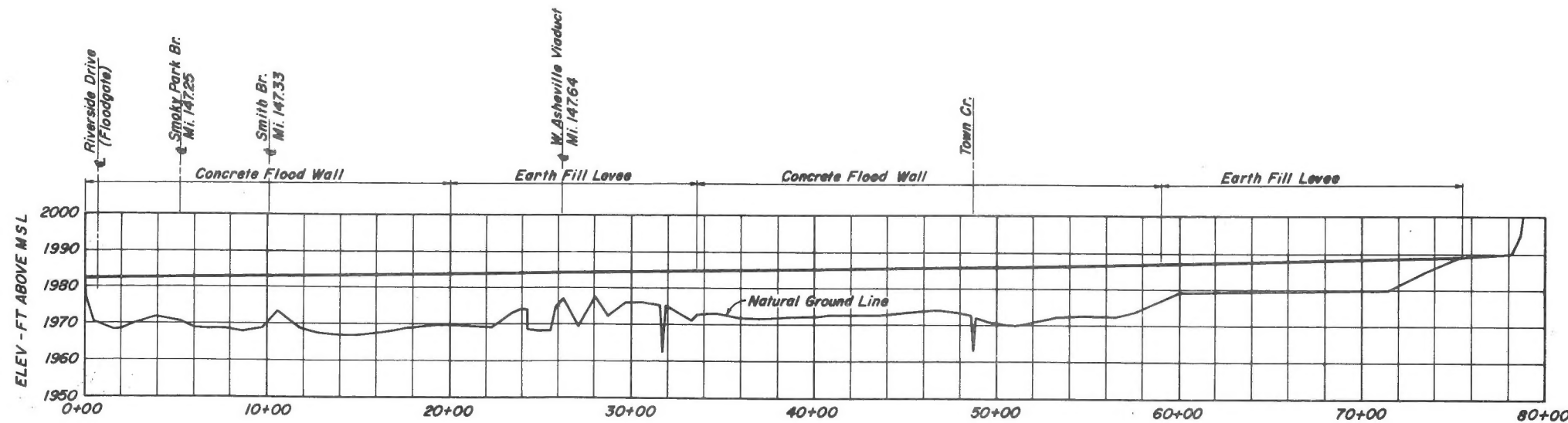
CHANNEL CAPACITIES
EXISTING AND IMPROVED
CONDITIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

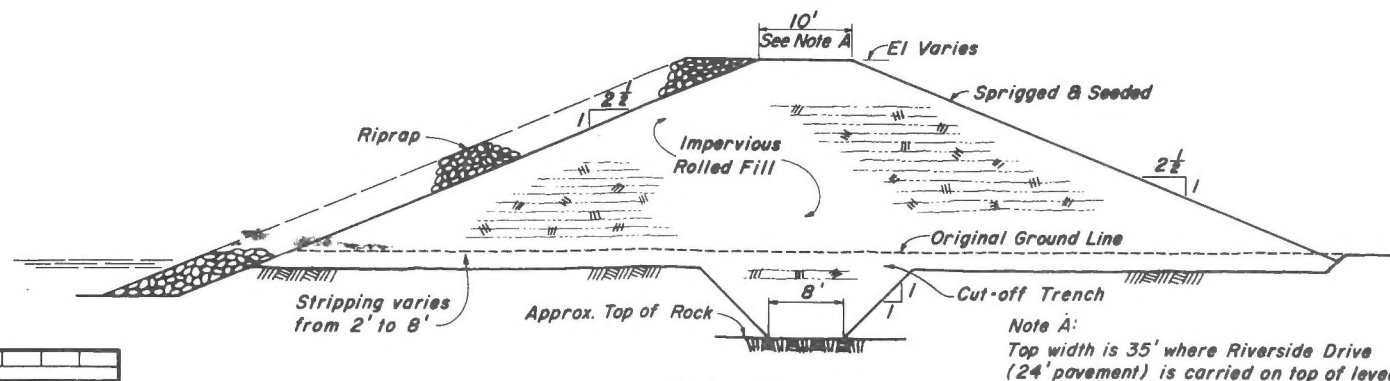
SUBMITTED	RECOMMENDED	APPROVED
KNOXVILLE	3-16-66 778 PP 1	321B2031R



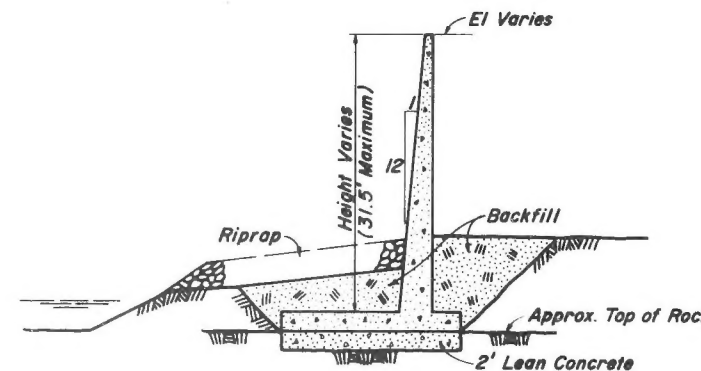
PLAN



PROFILE ALONG LEVEE



EARTH FILL LEVEE
TYPICAL SECTION



CONCRETE FLOOD WALL
TYPICAL SECTION

FLOOD PLAN STRUCTURES

- | | |
|-------------------------------------|-----------------------------------|
| 1 - Hunter Funeral Supply Co. | 23 - Post Machinery Co. |
| 2 - Hunter Funeral Supply Co. | 24 - Texaco Oil Bulk Plant |
| 3 - TransCarolina Concrete | 25 - Trading Post |
| 4 - Planters Tobacco Whse. | 26 - Citizens Fuel Co. |
| 5 - J. M. Westall Co. | 27 - Broad River Processing Co. |
| 6 - C&S Equipment | 28 - Asheville Livestock Yards |
| 7 - Earl Chesterfield Mills, Office | 29 - Stock Yard Cafe |
| 8 - Bonitz Insulating Co. | 30 - Asheville Stock Yard Office |
| 9 - Jerry Sternberg Co. | 31 - Georgia's Trading Post |
| 10 - Slosman Co. | 32 - Removed |
| 11 - Clyde Eby, Inc. | 33 - Removed |
| 12 - All-Aluminum Co. | 34 - Southern Railway Yard Office |
| 13 - Leemon Dist. Co. | 35 - Day's Tobacco Warehouse |
| 14 - Asheville Ice & Storage Co. | 36 - Southern Railway Sawmill |
| 15 - Asheville Ice & Storage Co. | 37 - Beacon Mfg. Co. |
| 16 - Beacon Blanket Co. Whse. | 38 - Day's Stock Yard Cafe |
| 17 - Robertson & Baker Garage | 39 - Day's Whse. Vacant |
| 18 - Ned Wheeler Brokerage Co. | 40 - Day's Warehouse |
| 19 - Abandoned | 41 - Standard Milling Co. |
| 20 - Public Service Co. of N. C. | 42 - Day's Warehouse |
| 21 - Ballards Truck Stop Cafe | 43 - Ness Brothers Co. |
| 22 - Denison Manufacturing Co. | 44 - Ryder Truck Rentals |

Scale 400 0 400 800 Feet
PLAN & PROFILE

Scale 10 0 10 20 Feet
SECTIONS

FRENCH BROAD RIVER-MILE 147 TO MILE 149

ASHEVILLE LEVEE
PLAN, PROFILE & SECTIONS

FRENCH BROAD RIVER IN N.C.
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
<i>Deo. W. Hamilton</i>	<i>Robert M. Nelson</i>	<i>R. E. Smith</i>
KNOXVILLE	12-23-64 77X PP 1	150K 21

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BUNCOMBE COUNTY PUBLIC LIBRARIES



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